Ministry of
Northern Development
and Mines
Ontario

Aggregate Resources Inventory of
The Towns Of Innisfil And Bradford West Gwillimbury
Simcoe County

Ontario Geological Survey
Aggregate Resources Inventory
Paper 114

By Staff of the Engineering and Terrain Geology Section,
Ontario Geological Survey

1991

92-03413/

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ISSN 0708-2061
ISBN 0-7743-8040-3

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Canadian Cataloguing in Publication Data

Main entry under title:

Aggregate resources inventory of the towns of Innisfil and Bradford West Gwillimbury, Simcoe County

(Ontario Geological Survey aggregate resources inventory paper, ISSN 0708-2061 ; 114)
Includes bibliographical references.
ISBN 0-7743-8040-3

1. Aggregates (Building materials)--Ontario--Innisfil.
2. Aggregates (Building materials)--Ontario--Bradford.
I. Ontario Geological Survey. Engineering and Terrain Geology Section.
II. Ontario. Ministry of Northern Development and Mines.
III. Series.

TN939.A33 1991 553.6'2'0971317 C91-092551-8

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Parts of this publication may be quoted if credit is given. It is recommended that reference be made in the following form:

Ontario Geological Survey 1991. Aggregate resources inventory of the towns of Innisfil and Bradford West Gwillimbury; Ontario Geological Survey, Aggregate Resources Inventory Paper 114, 41p.

500-91-Maracle Press

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Abstract

This report includes both an inventory and evaluation of sand and gravel as well as bedrock resources in the towns of Innisfil and Bradford West Gwillimbury. The report is part of the Aggregate Resources Inventory Program for areas designated under the Aggregate Resources Act.

In the report area, 3 deposits have been selected for possible resource protection at the primary level of significance. Selected Sand and Gravel Resource Area 1 consists of two beach deposits associated with glacial Lake Algonquin. Resource Area 2 consists of gravelly outwash. These areas occupy 840 acres (340 ha), exclusive of licenced properties. An estimated 465 acres (188 ha) are currently available for extraction, containing resources of approximately 17 million tons (15 million tonnes).

Several deposits have also been selected at the secondary level of significance. Although these deposits are not considered to be the "best" resources, they increase the towns' total aggregate supply considerably.

Generally, the towns contain resources of mainly sandy aggregate suitable for uses such as Granular Base Course B and C, and select subgrade material. Resources of crushable gravel, suitable for higher specification uses, are limited. Care should be taken to ensure the continuing availability of as much of these resources as possible.

The surficial material is underlain by bedrock of the Verulam, Lindsay, Blue Mountain and Georgian Bay formations. The resource protection and/or development of these possible resources is prohibited by the great thickness of glacial sediments which overlie the bedrock surface.

Selected Resource Areas are not intended to be permanent, single land use units. They represent areas in which a major resource is known to exist and may be reserved wholly or partially for extractive development and/or resource protection.

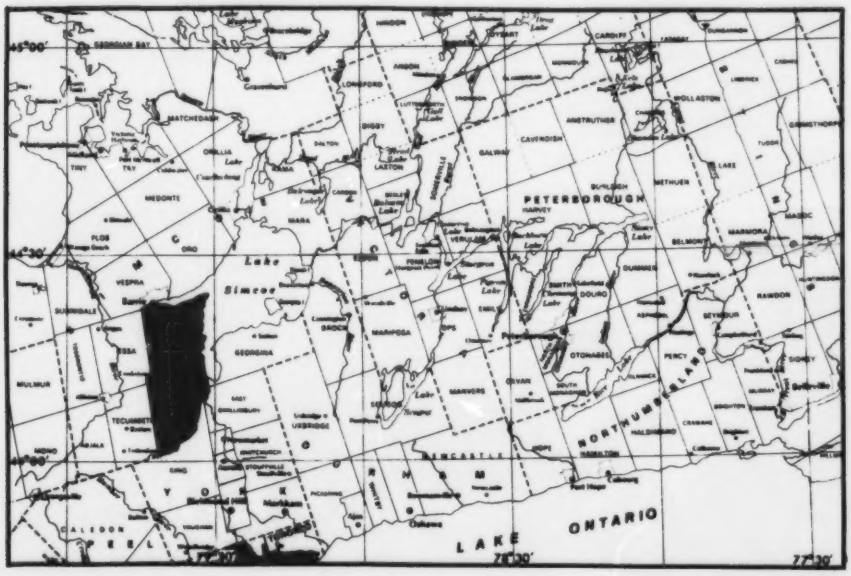

Figure 1. Key map showing the location of the towns of Innisfil and Bradford West Gwillimbury, scale 1:1 800 000.

Résumé

Ce rapport comprend à la fois un inventaire et une estimation des ressources en sable et en gravier ainsi que des ressources du substratum rocheux des villes de Innisfil et Bradford West Gwillimbury. Il fait partie du programme sur l'Inventaire des ressources en agrégat pour les secteurs régis par la Loi sur les ressources en agrégat.

Dans le secteur décrit dans ce rapport, trois dépôts ont été sélectionnés comme réserves possibles de ressources de première importance. La zone No 1 de ressources en sable et gravier comprend deux dépôts de plage associés au lac glaciaire Algonquin. La zone No 2 de ressources consiste de graviers d'épandage fluvio-glaciaire. Ces zones occupent 840 acres (340 ha), à l'exclusion des propriétées enregistrées. On estime que 465 acres (340 ha) sont actuellement disponibles pour l'extraction, contenant des ressources estimées à 17 millions de tonnes courtes (15 millions de tonnes métriques).

Plusieurs dépôts ont aussi été sélectionnés au deuxième niveau d'importance. Bien que ces dépôts ne soient pas considérés comme les «meilleures» ressources, il permettent d'augmenter considérablement les réserves totales en agrégat des villes concernées.

D'une manière générale, ces villes possèdent des ressources en agrégat sableux convenant pour des usages tels que les fondations granulaires B et C, et du matériau de moindre qualité. Les ressources en gravier concassable, qui conviennent pour des usages aux spécifications plus élevées sont limitées. Il faut signaler qu'il serait prudent de ménager ces ressources autant que possible afin d'en assurer la disponibilité à long terme.

Les matériaux superficiels recouvrent le substratum rocheux des formations de Verulam, Lindsay, Blue Mountain et Georgian Bay. La protection et/ou le développement de ces ressources éventuellles sont rendues impossibles par la grande épaisseur des sédiments glaciaires qui recouvrent la surface du substratum rocheux.

Les zones sélectionnées pour leurs ressources ne sont pas destinées à être réservées à un seul usage permanent. Elles représentent des zones où une ressource importante a été reconnue et peut être réservée en totalité ou en partie pour l'exploitation et/ou en tant que réserve de ressources.

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Aggregate Resources Inventory of
The Towns Of Innisfil And Bradford West Gwillimbury
Simcoe County

By Staff[1] of the Engineering and Terrain Geology Section

1. Project Supervisor: I. Szoke and Dale W. Scott; field work and report by G. Jones; compilation and drafting by Staff of the Aggregate Assessment Office. The Mineral Resources Staff of Huronia District Office and South Region of the Ministry of Natural Resources assisted in the collection of data, field checking and review of this report.

Manuscript accepted for publication by the Chief, Engineering and Terrain Geology Section, September 16, 1991. This report is published with the permission of V.G. Milne, Director, Ontario Geological Survey.

Introduction

Mineral aggregates, which include bedrock-derived crushed stone as well as naturally formed sand and gravel, constitute the major raw material in Ontario's road-building and construction industries. Very large amounts of these materials are used each year throughout the Province. For example, in 1987, the total tonnage of mineral aggregates extracted was 156 million tons (142 million tonnes), greater than that of any other metallic or nonmetallic commodity mined in the Province (Ontario Ministry of Northern Development and Mines 1989).

Although mineral aggregate deposits are plentiful in Ontario, they are fixed-location, nonrenewable resources which can be exploited only in those areas where they occur. Mineral aggregates are characterized by their high bulk and low unit value so that the economic value of a deposit is a function of its proximity to a market area as well as its quality and size. The potential for extractive development is usually greatest in urban fringe areas where land use competition is extreme. For these reasons the availability of adequate resources for future development is now being threatened in some areas.

Comprehensive planning and resource management strategies are required to make the best use of available resources, especially in those areas experiencing rapid development. Such strategies must be based on a sound knowledge of the total mineral aggregate resource base at both local and regional levels. The purpose of the Aggregate Resources Inventory is to provide the basic geological information required to include potential mineral aggregate resource areas in planning strategies and official plans. The reports should form the basis for discussion on those areas best suited for possible extraction. The aim is to assist decision-makers in protecting the public well-being by ensuring that adequate resources of mineral aggregate remain available for future use.

This report is a technical background document, based for the most part on geological information and interpretation. It has been designed as a component of the total planning process and should be used in conjunction with other planning considerations, to ensure the best use of a municipality's resources.

The report includes an assessment of sand and gravel resources as well as a discussion on the potential of bedrock-derived aggregate. The most recent information available has been used to prepare the report. As new information becomes available, revisions may be necessary.

Part I — Inventory Methods

FIE'.D AND OFFICE METHODS

The methods used to prepare the report primarily involve the interpretation of published geological data such as bedrock and surficial geology maps and reports (*see* References) as well as field examination of potential resource areas. Field methods include the examination of natural and man-made exposures of granular material. Most observations are made at quarries and sand and gravel pits located from records held by the Ontario Ministry of Transportation, the Ontario Geological Survey, and by Regional and District Offices of the Ontario Ministry of Natural Resources. Observations made at pit sites include estimates of the total face height and the proportion of gravel- and sand-sized fragments in the deposit. Observations are also made of the shape and lithology of the particles. These characteristics are important in estimating the quality and quantity of the aggregate. In areas of limited exposure, subsurface materials may be assessed by hand augering and test pitting, supplemented by test hole drilling, and geophysical surveys using hammer seismic equipment. The symbols for and locations of sample sites, test hole sites, and geophysical traverse lines are noted on Map 1.

Deposits with potential for further extractive development or those where existing data are scarce, are studied in greater detail. Representative layers in these deposits are sampled in 25- to 100-pound (11 to 45 kg) units from existing pit faces or from test pits. The samples are analysed for grain size distribution, and in some cases absorption, Los Angeles abrasion, and Magnesium Sulphate soundness tests and petrographic analyses are carried out. Analyses are performed either in the laboratories of the Soils and Aggregates Section, Engineering Materials Office, Ontario Ministry of Transportation, or in the Geoscience Laboratory, Ontario Geological Survey.

The field data are supplemented by pit information on file with the Soils and Aggregates Section of the Ontario Ministry of Transportation. Data contained in these files include field estimates of the depth, composition and "workability" of deposits, as well as laboratory analyses of the physical properties and chemical suitability of the aggregate. Information concerning the development history of the pits and acceptable uses of the aggregate is also recorded. The location, size and depth of extraction of pits licenced under the Aggregate Resources Act are obtained from records held by Regional and District Offices of the Ontario Ministry of Natural Resources. The co-operation of the above-named groups in the compilation of inventory data is gratefully acknowledged.

Aerial photographs at various scales are used to determine the continuity of deposits, especially in areas where information is limited. Water well records, held by the Ontario Ministry of the Environment, are used in some areas to corroborate deposit thickness estimates or to indicate the presence of buried granular material. These records are used in conjunction with other evidence.

Topographic maps of the National Topographic System, at a scale of 1:50 000, are used as a compilation base for the field and office data. The information is then transferred to a base map, also at a scale of 1:50 000. These base maps are prepared by the Land and Resource Information Branch, Ontario Ministry of Natural Resources with information taken from maps of the National Topographic System by permission of Energy, Mines and Resources Canada, for presentation in the report.

RESOURCE TONNAGE CALCULATION TECHNIQUES

SAND AND GRAVEL RESOURCES

Once the interpretative boundaries of the aggregate units have been established, quantitative estimates of the possible resources available can be made. Generally, the volume of a deposit can be calculated if its areal extent and average thickness are known or can be estimated. The computation methods used are as follows. First, the area of the deposit, as outlined on the final base map, is calculated in acres. The thickness values used are an approximation of the deposit thickness, based on the face heights of pits developed in the deposit or on subsurface data such as test holes and water well logs. Original tonnage values can then be calculated by multiplying the volume of the deposit by 2500 (the density factor). This factor is approximately the number of tons in a one-foot (0.3 m) thick layer of sand and gravel, one acre (0.4 ha) in extent, assuming an average density of 110 pounds per cubic foot (1766 kg/m^3).

Tonnage = Area x Thickness x Density Factor

Tonnage calculated in this manner must be considered only as an estimate. Furthermore, such tonnages represent amounts that existed prior to any extraction of material (i.e., original tonnage) (Table 1, Column 4).

The Selected Sand and Gravel Resource Areas in Table 3 are calculated in the following way. Two successive subtractions are made from the total area. Column 3 accounts for the number of acres unavailable because of the presence of permanent cultural features and their associated setback requirements. Column 4 accounts for those areas that have previously been extracted (e.g., wayside and abandoned pits are included in this category). The remaining figure is the area of the deposit currently available for extraction (Column 5). The available area is then multiplied by the estimated deposit thickness and the density factor (Column 5 x Column 6 x 2500) to give an estimate of the sand and gravel tonnage

(Column 7) presently available for extractive development and/or resource protection.

Reserve estimates are calculated for deposits of primary significance. Reserve estimates for deposits of secondary and tertiary significance are not calculated in Table 3, however, the aggregate potential of these deposits is discussed in the report.

BEDROCK RESOURCES

The method used to calculate resources of bedrock-derived aggregate is much the same as that described above. The areal extent of bedrock formations overlain by less than 50 feet (15 m) of unconsolidated overburden is determined from bedrock geology maps, drift thickness and bedrock topography maps, and from the interpretation of water well records. The measured extent of such areas is then multiplied by the estimated quarriable thickness of the formation, based on stratigraphic analyses and on estimates of existing quarry faces in the unit. In some cases a standardized estimate of 60 feet (18 m) is used for thickness. Volume estimates are then multiplied by the density factor [the estimated weight in tons of a one-foot (0.3 m) thick section of rock, one acre (0.4 ha) in extent].

Resources of dolostone are calculated using a density factor of 165 pounds per cubic foot (2649 kg/m^3) or 3600 tons per acre (8070 t/ha). Sandstone resources are calculated using a density estimate of 146 pounds per cubic foot (2344 kg/m^3) and shale resources are calculated with a factor of 150 pounds per cubic foot (2408 kg/m^3).

UNITS AND DEFINITIONS

Although most of the measurements and other primary data available for resource tonnage calculations are given in Imperial units, Metric units have also been given in the text and on the tables which accompany the report. The Metric equivalent of the data is shown in brackets after or directly below the corresponding Imperial figures. Data are generally rounded off in accordance with the Ontario Metric Practice Guide (Metric Committee 1975).

The tonnage estimates made for sand and gravel deposits are termed possible resources (*see* Glossary, Appendix B) in accordance with terminology of the Ontario Resource Classification Scheme (Robertson 1975, p.7) and with the Association of Professional Engineers of Ontario (1976).

Part II — Data Presentation and Interpretation

Three maps, each portraying a different aspect of the aggregate resources in the municipality, accompany the report. Map 1, "Distribution of Sand and Gravel Deposits", gives a comprehensive inventory of the sand and gravel resources in the report area. Map 2, "Selected Sand and Gravel Resource Areas", shows those deposits which are considered to represent the largest and/or highest quality resources in the area. Map 3, "Bedrock Resources" shows the distribution of bedrock formations, the thickness of overlying unconsolidated sediments, and identifies the Selected Bedrock Resource Areas.

MAP 1: DISTRIBUTION OF SAND AND GRAVEL DEPOSITS

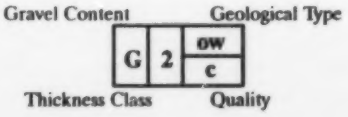
Map 1 is derived from existing surficial geology maps of the area or from aerial photograph interpretation in areas where surficial mapping is incomplete. The map shows the extent and quality of sand and gravel deposits within the study area and the present level of extractive activity.

On the map, gravel deposits are indicated by dark brown shading while sand deposits are shaded light brown. The present level of extractive activity is also indicated. Those areas which are licenced for extraction under the Aggregate Resources Act are shown by a solid outline and identified by a number which refers to the pit descriptions in Table 2. Each description notes the owner/operator, location and licenced acreage of the pit, as well as the estimated face height and percentage gravel. A number of unlicenced pits (abandoned pits or wayside pits operating on demand under authority of a permit) are identified by a numbered dot on Map 1 and described in Table 2. Similarly, test hole locations appear on Map 1 as a point symbol and are described in Table 7. Geophysics lines are shown on Map 1 by a line symbol and are interpreted in Table 8.

Map 1 also presents a summary of available information related to the quality of aggregate contained in all the known aggregate deposits in the study area. Much of this information is contained in the symbols which are found on the map. The Deposit Symbol appears for each mapped deposit and summarizes important genetic and textural data. The Texture Symbol is a circular proportional diagram which displays the grain size distribution of the aggregate in areas where bulk samples were taken.

DEPOSIT SYMBOL

The Deposit Symbol is similar to those used in soil mapping and land classification systems commonly in use in North America. The components of the symbol indicate the gravel content, thickness of material, origin (type) and quality limitations for every deposit shown on Map 1. These components are illustated by the following example:



This symbol identifies an outwash deposit 10 to 20 feet (3 to 6 m) thick containing more than 35% gravel. Excess silt and clay may limit uses of the aggregate in the deposit.

The "gravel content" and "thickness class" are basic criteria for distinguishing different deposits. The "gravel content" symbol is an upper case "S" or "G". The "S" indicates that the deposit is generally "sandy" and that gravel-sized aggregate (greater than 4.75 mm) makes up less than 35% of the whole deposit. "G" indicates that the deposit contains more than 35% gravel.

The "thickness class" indicates a depth range which is related to the potential resource tonnage for each deposit. Four thickness class divisions have been established as shown in the legend for Map 1.

Two smaller sets of letters, divided from each other by a horizontal line, follow the thickness class number. The upper series of letters identifies the geologic deposit type (the deposit types are summarized with respect to their main geologic and extractive characteristics in Appendix C) and the lower series of letters identifies the main quality limitations that may be present in the deposit as discussed in the next section.

TEXTURE SYMBOL

The Texture Symbol provides a more detailed assessment of the grain size distribution of material sampled during field study. These symbols are derived from the information plotted on the aggregate grading curves found in the report. The relative amounts of gravel, sand, and silt and clay in the sampled material are shown graphically in the Texture Symbol by the subdivision of a circle into proportional segments. The following example shows a hypothetical sample consisting of 30% gravel, 60% sand and 10% silt and clay:

MAP 2: SELECTED SAND AND GRAVEL RESOURCE AREAS

Map 2 is an interpretative map derived from an evaluation of the deposits shown on Map 1. The deposits identified on Map 2 are those which are considered to be im-

portant in ensuring an adequate resource base for the future.

All the selected sand and gravel resource areas are first delineated by geological boundaries and then classified into three levels of significance: primary, secondary and tertiary. Each area of primary significance is given a deposit number and all such deposits are shown by dark red shading on Map 2.

Selected Sand and Gravel Resource Areas of primary significance are not intended to be permanent, single land use units. They represent areas in which a major resource is known to exist and may be reserved wholly or partially for extractive development and/or resource protection.

Deposits of secondary significance are indicated by light red shading on Map 2. Such deposits are believed to contain significant amounts of sand and gravel. Although deposits of secondary significance are not considered to be the "best" resources in the report area, they may contain large quantities of sand and gravel and should be considered as part of the aggregate supply of the area.

Areas of tertiary significance are outlined on the map by a solid line but have no shading. They are not considered to be important resource areas because of their low available resources, or because of possible difficulties in extraction. Such areas may be useful for local needs but are unlikely to support large-scale development.

The process by which deposits are evaluated and selected involves the consideration of two sets of criteria. The main selection criteria are site specific, related to the characteristics of individual deposits. Factors such as deposit size, aggregate quality, and deposit location and setting are considered in the selection of those deposits best suited for extractive development. A second set of criteria involves the assessment of local aggregate resources in relation to the quality, quantity, and distribution of resources in the region in which the report area is located. The intent of such a process of evaluation is to ensure the continuing availability of sufficient resources to meet possible future demands.

SITE SPECIFIC CRITERIA

Deposit Size

Ideally, selected deposits should contain available sand and gravel resources large enough to support a commercial pit operation using a stationary or portable processing plant. In practice, much smaller deposits may be of significant value depending on the overall reserves in the rest of the municipality. Generally, deposits in Class 1 [greater than 20 feet (6 m) thick] and containing more than 35% gravel are considered to be most favourable for commercial development. Thinner deposits may be valuable in municipalities with low total resources.

Aggregate Quality

The limitations of natural aggregates for various uses result from variations in the lithology of the particles composing the deposit, and from variations in the size distribution of these particles.

Four indicators of the quality of aggregate may be included in the deposit symbols on Map 1. They are: gravel content (G or S), fines (C), oversize (O) and lithology (L).

Three of the quality indicators deal with grain size distribution. The gravel content (G or S) indicates the suitability of aggregate for various uses. Deposits containing at least 35% gravel in addition to a minimum of 20% material greater than the 26.5 mm sieve are considered to be the most favourable extractive sites, since this content is the minimum from which crushed products can be economically produced.

Excess fines (high silt and clay content) may severely limit the potential use of a deposit. Fines content in excess of 10% may impede drainage in road subbase aggregate and render it more susceptible to the effects of frost action. In asphalt aggregate, excess fines hinder the bonding of particles. Deposits known to have a high fines content are indicated by a "C" in the quality portion of the Deposit Symbol.

Deposits containing more than 20% oversize material [greater than 4 inches (10 cm) in diameter] may also have use limitations. The oversize component is unacceptable for all concrete aggregate and for road-building aggregate, so it must be either crushed or removed during processing. Deposits known to have an appreciable oversize component are indicated by an "O" in the quality portion of the Deposit Symbol.

Another indicator of the quality of an aggregate is lithology. Just as the unique physical and chemical properties of bedrock types determine their value for use as crushed rock, so do various lithologies of particles in a sand and gravel deposit determine its suitability for various uses. The presence of objectionable lithologies such as chert, siltstone and shale, even in relatively small amounts, can result in a reduction in the quality of an aggregate, especially for high quality uses such as concrete and asphalt. Similarly, highly weathered, very porous and friable rock can restrict the quality of an aggregate. Deposits known to contain objectionable lithologies are indicated by an "L" in the quality component of the Deposit Symbol.

If the Deposit Symbol shows either "C", "O", or "L" or any combination of these indicators, the quality of the deposit is considered to be reduced for some uses of the aggregate. No attempt is made to quantify the degree of limitation imposed. Assessment of the four indicators is made from published data, from data contained in files of both the Ontario Ministry of Transportation and the Engineering and Terrain Geology Section of the Ontario Geological Survey, and from field observations.

Quality data may also appear in Table 9, where the results of aggregate quality tests are listed by test type and sample location. The types of tests conducted and

the test specifications are explained in Appendixes B and E, respectively.

Analyses of unprocessed samples obtained from test holes, pits or sample sites are plotted on grain size distribution graphs. On the graphs are the Ontario Ministry of Transportation's gradation specification envelopes for aggregate products: Granular Base Course A, B and C, Hot-Laid Asphaltic Sand Nos. 1,2,3,4 and 8, and concrete sand. By plotting the gradation curves with respect to the specification envelopes, it can be determined how well the unprocessed sampled material meets the criteria for each product. These graphs, called Aggregate Grading Curves, follow the tables in the report.

Location and Setting

The location and setting of a resource area has a direct influence on its value for possible extraction. The evaluation of a deposit's setting is made on the basis of natural and man-made features which may limit or prohibit extractive development.

First, the physical context of the deposit is considered. Deposits with some physical constraint on extractive development, such as thick overburden or high water table, are less valuable resource areas because of the difficulties involved in resource recovery. Second, permanent man-made features, such as roads, railways, powerlines, and housing developments, which are built on a deposit, may prohibit its extraction. The constraining effect of legally required setbacks surrounding such features is included in the evaluation. A quantitative assessment of these constraints can be made by measurement of their areal extent directly from the topographic maps. The area rendered unavailable by these features is shown for each resource area in Table 3 (Column 3).

The assessment of sand and gravel deposits with respect to local land use and to private land ownership is an important component of the general evaluation process. These aspects of the evaluation process are not considered further in this report, but readers are encouraged to discuss them with personnel of the pertinent District Office of the Ontario Ministry of Natural Resources.

REGIONAL CONSIDERATIONS

In selecting sufficient areas for resource development, it is important to assess both the local and the regional resource base, and to forecast future production and demand patterns.

Some appreciation of future aggregate requirements in an area may be gained by assessing its present production levels and by forecasting future production trends. Such an approach is based on the assumptions that production levels in an area closely reflect the demand and that the present production "market share" of an area will remain roughly at the same level.

The aggregate resources in the region surrounding a municipality should be assessed in order to properly evaluate specific resource areas and to adopt optimum resource management plans. For example, a municipality that has large resources in comparison to its surrounding region constitutes a regionally significant resource area. Municipalities with high resources in proximity to large demand centres, such as metropolitan areas, are special cases.

Although an appreciation of the regional context is required to develop comprehensive resource management techniques, such detailed evaluation is beyond the scope of this report. The selection of resource areas made in this study is based primarily on geological data or on considerations outlined in preceding sections.

MAP 3: BEDROCK RESOURCES

Map 3 is an interpretative map derived from bedrock geology, drift thickness and bedrock topography maps, water well data from the Ontario Ministry of the Environment, oil and gas well data from the Petroleum Resources Section (Ontario Ministry of Natural Resources) and from geotechnical test hole data from various sources. Map 3 is based on concepts similar to those outlined for Maps 1 and 2, but displays both the inventory and evaluation on the one map.

The geological boundaries of the bedrock units are shown by a dashed line. Isolated outcrops are indicated by an "X". Three sets of contour lines delineate areas of less than 3 feet (1 m) of drift, areas of 3 to 25 feet (1 to 8 m) of drift, and areas of 25 to 50 feet (8 to 15 m) of drift. The extent of these areas of thin drift are shown by three shades of blue. The darkest shade indicates where bedrock outcrops or is within 3 feet (1 m) of the ground surface. These areas constitute potential resource areas because of their easy access. The medium shade indicates areas where drift cover is up to 25 feet (8 m) thick. Quarrying is possible in this depth of overburden and these zones also represent potential resource areas. The lightest shade indicates bedrock areas overlain by 25 to 50 feet (8 to 15 m) of overburden. These latter areas constitute resources which have extractive value only in specific circumstances. Outside of these delineated areas, the bedrock can be assumed to be covered by more than 50 feet (15 m) of overburden, a depth generally considered to be too great to allow economic extraction (unless part of the overburden is composed of economically attractive deposits).

Other inventory information presented on Map 3 is designed to give an indication of the present level of extractive activity in the report area. Those areas which are licenced for extraction under the Aggregate Resources Act are shown by a solid outline and identified by a number which refers to the quarry descriptions in Table 5. Each description notes the owner/operator, location, licenced acreage and an estimate of face height. Unlicenced quarries (abandoned quarries or wayside quarries operating on demand under authority of a permit) are also identified and numbered on Map 3 and de-

scribed in Table 5. Two additional symbols may appear on the map. An open dot indicates the location of a selected water well which penetrates bedrock. The overburden thickness is shown in feet beside the open dot. Similarly, test hole locations appear as a point symbol with the depth to bedrock shown in feet beside it. The test holes may be further described in Table 7.

SELECTION CRITERIA

Criteria equivalent to those used for sand and gravel deposits are used to select bedrock areas most favourable for extractive development.

The evaluation of bedrock resources is made primarily on the basis of performance and suitability data established by laboratory testing at the Ontario Ministry of Transportation. The main characteristics and uses of the bedrock units found in southern Ontario are summarized in Appendix D.

Deposit "size" is related directly to the areal extent of thin drift cover overlying favourable bedrock formations. Since vertical and lateral variations in bedrock units are much more gradual than in sand and gravel deposits, the quality and quantity of the resource are usually consistent over large areas.

Quality of the aggregate derived from specific bedrock units is established by the performance standards previously mentioned. Location and setting criteria and regional considerations are identical to those for sand and gravel deposits.

SELECTED RESOURCE AREAS

Selection of Bedrock Resource Areas has been restricted to a single level of significance. Three factors support this approach. First, quality and quantity variations are gradual. Second, the areal extent of a given quarry operation is much smaller than that of a sand and gravel pit producing an equivalent tonnage of material, and third, since crushed bedrock has a higher unit value than sand and gravel, longer haul distances can be considered. These factors allow the identification of alternative sites having similar development potential. The Selected Areas, if present, are shown on Map 3 by a line pattern and the calculated available tonnages are given in Table 6.

Selected Bedrock Resource Areas shown on Map 3 are not permanent, single land use units. They represent areas in which a major bedrock resource is known to exist and may be reserved wholly or partially for extractive development and/or resource protection.

Part III - Assessment of Aggregate Resources in the Towns of Innisfil and Bradford West Gwillimbury

LOCATION AND POPULATION

The towns of Innisfil and Bradford West Gwillimbury occupy a total area of 120 502 acres (48 767 ha) in the southeastern part of Simcoe County. Part of the city of Barrie along with the former town of Bradford and the former village of Cookstown are also situated within the study area. The towns are shown on parts of the Alliston (31 D/4) and Barrie (31 D/5) map sheets of the National Topographic System, at a scale of 1:50 000.

The combined population of the towns of Innisfil and Bradford West Gwillimbury was 36 897 in 1988, exclusive of the city of Barrie (Ontario Ministry of Municipal Affairs 1991). Outside of Barrie and the former town of Bradford, the majority of the residents are engaged in farming or are rural-residential inhabitants. There is also a large recreational population along the shore of Lake Simcoe. The Holland Marsh, an important vegetable growing area, is situated along the southeastern border of the town of Bradford West Gwillimbury.

Access to resource areas within the towns is provided by King's highways 9, 11, 27, 88, 89, 90 and 400, together with county and town roads. King's Highway 400, a major multi-lane highway, along with King's highways 11 and 27, run north-south through the towns, linking them with major population centres to the south. Two lines of the Canadian National Railways also pass through the towns.

PHYSIOGRAPHY AND SURFICIAL GEOLOGY

The physiography and distribution of unconsolidated sediments, including sand and gravel deposits, are the result of glacial activity which took place during the Late Wisconsinan Substage of the Pleistocene Epoch, informally known as the "Great Ice Age". This substage, which lasted from approximately 23 000 to 10 000 years ago, was marked by the repeated advance and retreat of massive, continental ice sheets.

These towns have been covered several times by a lobe of the continental ice sheet which advanced in a southwesterly direction out of the Lake Simcoe basin. Several tills were deposited by the advancing ice lobe. Two of these tills, an older sand to silty sand till and a younger clayey silt to silt till, form an extensive till plain in the area (Gwyn and White 1973). A number of drumlins have been developed on this till plain and the plain is included in the physiographic region known as the Peterborough drumlin field (Chapman and Putnam 1984). The drumlins are streamlined, elongated hills which are oriented in a general northeast direction, parallel to the regional ice flow. Pockets of stratified sand and gravel are occasionally associated with the drumlins and this material has been extracted for local use. Other features, referred to as "ice block ridges" (Deane 1950), occur as groups of low ridges on the till plain and indicate stagnant ice conditions as the ice margin retreated from the area.

Several deposits consisting of ice-contact stratified sand and gravel were deposited along the ice-margin by meltwaters flowing off the ice. The ice-contact features either occur as isolated bodies associated with ridges or as accumulations of silts and sands along valley sides (Deane 1950). The most extensive of these features extends south from Barrie to near the southern boundary of the town of Innisfil. A number of pits have been developed in this ice-contact stratified drift.

Many outwash deposits are also evident. They consist of well stratified sand and gravel that was deposited in front of the ice by meltwater streams. The largest outwash bodies occur south of Barrie along the western boundary of the town of Innisfil and in the northern part of the town of Bradford West Gwillimbury. A unique geological feature known as "The Hollows" exists in the large outwash deposit in the northern part of the town of Bradford West Gwillimbury. This feature is a large depression, that may have been formed by the melting of a large block of stranded ice. Outwash deposits have been an important source of aggregate in the area.

An additional sand and gravel outwash deposit occurs along a till ridge in the northeastern corner of the town of Innisfil near Peninsular Park. The material exposed in this deposit consists of well stratified sandy gravel that has been buried beneath younger sediments. The gravel may have been deposited in a subaqueous outwash or deltaic environment.

As the glacier withdrew from the area, a number of small lakes developed in depressions in the land surface south of the ice margin (Gwyn and White 1973). In these lakes, clay and silt were deposited and a large area in the southern part of the town of Bradford West Gwillimbury consists of these fine-grained sediments. This area has been included in the physiographic region known as the Schomberg clay plains (Chapman and Putnam 1984).

As the ice continued to retreat, waters of glacial Lake Algonquin inundated the Simcoe lowlands (Chapman and Putnam 1984). The Simcoe lowlands, in the report area, include the Innisfil Creek and Holland River valleys, as well as a strip of land along the shore of Lake Simcoe. A wave-cut scarp, located near the shore of Lake Simcoe at elevations between 775 and 800 feet (236 and 244 m) above sea level marks the highest level the waters reached in this lake. In the shallow waters of Lake Algonquin and successive lower lake stages, beaches, bars and spits were formed near the shoreline. These features generally consist of well stratified coarse sand and fine gravel and have been traditional aggregate

sources in the area. Glaciolacustrine plain sediments, consisting largely of silty fine sand, were also deposited in the shallow lake waters, while in the deeper waters, clay and silt were deposited.

Postglacial erosional and depositional processes have been of relatively minor importance in modifying the physiography of the towns. Alluvium has been deposited along several creeks in the area. Poor drainage in several depressions, notably the Holland River valley, has led to the development of large marshes or bog deposits.

EXTRACTIVE ACTIVITY

Seventy-three sand and gravel pits have been identified in the towns of Innisfil and Bradford West Gwillimbury. The majority of these have been developed in glaciolacustrine beach, outwash and ice-contact deposits. At the time of writing, 11 of these pits were licenced to operate. The licenced properties have a total area of 357.9 acres (144.8 ha). Many of the remaining pits were overgrown and abandoned.

Since designation of the two towns under the Pits and Quarries Act, records of the total annual production from all licenced sources have been maintained by the Huronia District Office of the Ontario Ministry of Natural Resources. The average annual production in the 9 year period between 1976 and 1984 was approximately 283 000 tons (257 000 tonnes).

SELECTED SAND AND GRAVEL RESOURCE AREAS

Map 1 indicates the deposits which contain granular materials. These deposits occupy a total area of approximately 37 000 acres (15 000 ha) and contain an original tonnage of 1690 million tons (1540 million tonnes). Many of these areas have limited value for resource development because of the amount of available resources or the quality of the material. Consequently, only the most significant sources are suggested for protection at the primary level of significance.

The sand and gravel deposits selected for possible resource protection are shown on Map 2. Two glaciolacustrine beach deposits and an outwash deposit have been selected as Sand and Gravel Resource Areas of primary significance. These resource areas have an estimated 465 acres (188 ha) currently available for extraction and contain granular resources of approximately 17 million tons (15 million tonnes).

A number of deposits have also been selected at the secondary level of significance. Although these deposits are not regarded as the "best" sources, they add significantly to the resource base of the towns and should be considered part of the total aggregate supply.

Overall, the towns contain only limited resources of crushable gravel and large possible resources of sandy aggregate suitable for low-specification use. The selected areas contain most of the presently known and available resources of crushable gravel. However, the deposits contain aggregate only marginally suitable for crushing. Care should be taken to ensure the continuing availability of as much of the remaining resources as possible.

Selected Sand and Gravel Resource Area 1

Selected Sand and Gravel Resource Area 1 consists of two north-trending glaciolacustrine beach deposits, labelled 1a and 1b on Map 2. Both deposits are located near the shore of Lake Simcoe in the eastern part of the town of Innisfil. They have been traditional aggregate sources and one licenced pit and 7 unlicenced pits have been opened in the resource area.

Area 1a is situated in the northeastern corner of the town, west of Sandy Cove. Faces in pits opened in this deposit (pit nos. 23, 24, 25 and 26) range in height from 5 to 15 feet (1.5 to 5 m) and expose well stratified sandy gravel. The material is generally of good quality and suitable for the production of a range of pit-run and crusher-run products including Hot-Laid (HL) No. 4 stone and granular base course. Sand control measures, however, may be necessary to produce a suitable crushed product. The sand fraction of the aggregate requires blending for use as hot-laid asphalt.

Area 1b is located in the southeastern part of the town near Lefroy. Four pits have been opened in the area, one of which is a licenced source (pit nos. 7, 34, 37 and 38). Faces in the pits expose between 5 and 20 feet (1.5 and 6 m) of well stratified gravelly sand, although concentrations of gravel were observed in places. The aggregate extracted from these pits is generally suitable for use as Granular Base Course (GBC) B and C. In sections where gravel is relatively more abundant, higher specification products such as GBC A may be produced with sand control. Blending would be required for the production of hot-laid asphaltic sand.

Resource Areas 1a and 1b total 435 acres (176 ha), exclusive of licenced properties. Cultural constraints, including the residential and commercial development at Lefroy, and previous extraction reduce the area currently available to 197 acres (80 ha). Assuming an average deposit thickness of 15 feet (5 m), available resources are estimated to be 7 million tons (6 million tonnes).

Selected Sand and Gravel Resource Area 2

Selected Sand and Gravel Resource Area 2 is an outwash deposit located east of Pinkerton in the central part of the town of Bradford West Gwillimbury. This deposit has been extensively utilized and 7 pits have been identified, including one which is currently licenced (pit nos. 11, 55, 57 to 61).

Faces in the pits range in height from 5 to 30 feet (1.5 to 9 m) and expose sandy fine gravel and gravelly sand. Throughout the deposit, the gravel beds are usual-

ly concentrated near the surface and overlie predominantly sandy aggregate. Test hole WG-TH-8, located in the deposit, revealed 15 feet (5 m) of fine to medium sand (Figures 3a and 3b). Although the resource area has been classified as a gravel source, the overall gravel content is marginal and concentrations of sandy aggregate occur.

The products most readily produced from this deposit include GBC B and C, and fill. In sections where gravel is relatively abundant, the material may also be suitable for use as GBC A and higher specification uses, with sand control. The sand fraction of the aggregate grades fine in places for hot-laid asphalt and blending would be required.

Resource Area 2 occupies 400 acres (162 ha), exclusive of the licenced property. Previous extraction and cultural constraints reduce the area currently available to 270 acres (109 ha). Assuming an average deposit thickness of 15 feet (5 m), available resources are estimated to total 10 million tons (9 million tonnes).

Resource Areas of Secondary Significance

A large outwash deposit situated in the western part of the town of Innisfil, south of Barrie has been designated a resource area of secondary significance. Six pits have been opened in this secondary area and the sandy aggregate exposed in the faces of the pits is generally suitable for use as GBC C, select subgrade material, and in places, for GBC B. MTO records indicate that higher specification products have been produced from some of the pits. The higher quality aggregate, however, has been depleted in these sources. The outwash was deposited on a rolling till plain and may vary considerably in thickness from one location to another (Deane 1950).

A small outwash deposit and an ice-contact deposit located near the former town of Bradford have also been selected at the secondary level of significance. The sand outwash deposit is located south of Resource Area 2 and contains pit no. 62. The pit face exposed 10 feet (3 m) of gravelly sand suitable for GBC B and C, and fill. A limited amount of quality aggregate may be available from the small ice-contact deposit which is situated north of Coulson's Hill. The gravel extracted from pit no. 52 in the deposit was acceptable for a range of pit-run and crusher-run products.

BEDROCK GEOLOGY

Bedrock underlying the report area consists of limestone and shale of Middle to Upper Ordovician age. From north to south, the bedrock includes the Verulam, Lindsay, Blue Mountain and Georgian Bay formations.

The oldest bedrock unit, the Verulam Formation, underlies the northern and northeastern part of the study area. The formation consists of pure to argillaceous limestone with interbedded shale. The Verulam strata are overlain by the Lindsay Formation, which occupies a large area in the central part of the two towns. The formation consists of fine-grained, argillaceous limestone (Liberty 1969). The Collingwood Member forms the upper part of the Lindsay Formation, and consists of organic-rich interbedded calcareous shales and limestones (Russell and Telford 1983). Neither the Verulam Formation nor the Lindsay Formation are well suited for the production of load-bearing aggregate. Both formations, however, have been quarried as raw material for lime and cement manufacture elsewhere in southern Ontario.

The Blue Mountain Formation shale overlies the Lindsay strata in the southwestern part of the town of Bradford West Gwillimbury. The formation consists of blue-grey, predominantly noncalcareous shale (Russell and Telford 1983). In the southwestern corner of the town, the Georgian Bay formation overlies the Blue Mountain Formation. The formation consists of thin- to medium-bedded siltstones, shaly limestones and shales. Neither of these two formations are considered to be sources of load-bearing aggregate.

In the report area, the bedrock is generally overlain by over 200 feet (61 m) of overburden and in places the drift thickness exceeds 500 feet (152 m). Consequently, extraction of the bedrock would be uneconomical.

SUMMARY

The sand and gravel deposits of the towns of Innisfil and Bradford West Gwillimbury are the product of glacial activity which occurred during the Late Wisconsinan. Three of these deposits have been selected at the primary level of significance. The Selected Resource Areas generally contain good quality aggregate suitable for the production of a variety of road-building and construction products. Secondary resource areas contain aggregate which may be used locally to supplement the primary sources.

Bedrock of the Verulam, Lindsay, Blue Mountain and Georgian Bay formations underlie the surficial material. However, the drift thickness is too great to permit the economic extraction of any possible bedrock resources.

Enquiries regarding the Aggregate Resources of the Towns of Innisfil and Bradford West Gwillimbury should be directed to the Aggregate Assessment Office, Ontario Geological Survey, Ministry of Northern Development and Mines, 7th Floor, 77 Grenville Street, Toronto, Ontario, M7A 1W4 [Tel. (416) 965-1663] or to the Resident Geologist, Ministry of Northern Development and Mines, Box 5463, 659 Exeter Road, London, Ontario, N6A 4L6 [Tel. (519) 661-2773], or to the Ontario Ministry of Natural Resources at the Huronia District Office, Midhurst, Ontario, L0L 1X0 [Tel. (705) 728-2900].

TABLE 1. TOTAL SAND AND GRAVEL RESOURCES, TOWNS OF INNISFIL AND BRADFORD WEST GWILLIMBURY.*

1 CLASS NO.	2 DEPOSIT TYPE (*see* Appendix C)	3 AREAL EXTENT Acres (Hectares)	4 ORIGINAL TONNAGE Millions of Tons (Tonnes)
Town of Innisfil			
1	G–OW–LD (buried)	255 (103)	26 (24)
	S–IC	6500 (2650)	405 (365)
	S–OW	930 (375)	58 (53)
2	G–LB	155 (63)	6 (5)
	S–IC	370 (150)	14 (13)
	S–IC (buried)	17 (7)	< 1 (< 1)
	S–LB	550 (223)	21 (19)
	S–LP	11 700 (4750)	440 (400)
	S–OW	3750 (1520)	141 (128)
3	G–LB	93 (38)	2 (2)
	S–IC	1000 (405)	15 (14)
	S–LB	115 (46)	2 (2)
	S–OW	236 (96)	5 (5)
4	G–OW	8 (3)	< 1 (< 1)
		25 500 (10 300)	1140 (1040)
Town of Bradford West Gwillimbury			
1	S–IC	14 (6)	< 1 (< 1)
	S–OW	4800 (1940)	300 (270)
2	G–IC	22 (9)	1 (< 1)
	G–LB	44 (18)	2 (2)
	G–OW	410 (166)	15 (14)
	S–LP	5100 (2050)	191 (173)
	S–OW	840 (340)	32 (29)
3	G–OW	115 (46)	2 (2)
	S–IC	6 (2)	< 1 (< 1)
	S–OW	109 (44)	2 (2)
4	G–OW	32 (13)	< 1 (< 1)
		11 500 (4650)	550 (490)
TOTAL FOR REPORT AREA:		37 000 (15 000)	1690 (1540)

* *Deposits within the city of Barrie, the former town of Bradford and the former village of Cookstown have been omitted on all tables.*

N.B. Minor variations in all tables are caused by rounding of data.

TABLE 2. SAND AND GRAVEL PITS, TOWNS OF INNISFIL AND BRADFORD WEST GWILLIMBURY.

1 NO.	2 MTO NO.	3 OWNER/OPERATOR	4 LOT	5 CONC.	6 LICENCED AREAS Acres (Hectares)	7 FACE HEIGHT Feet (Metres)	8 % GRAVEL
LICENCED PITS							
Town of Innisfil							
1	B3-056	846553 Ontario Ltd.	SE1/4 1 SW1/4 2	13 13	39.4 (15.9)	30-50 (9-15)	10-30 variable
2	-	John Ellis Constr. Ltd.	1	11	4.5 (1.8)	15 (5)	10-15
3	-	T.W. Bowman	N1/2 9	9	50.6 (20.5)	20 (6)	< 5
4	B3-067	Town of Innisfil	Pt.N1/2 26,27	13	20.0 (8.1)	30-50 (9-15)	30-40
5	B3-007	Lamstone Aggr. Supply Ltd.	Pt.N1/2 23	6	60.5 (24.5)	10-15 (3-5)	10-30
6	B3-084	796467 Ontario Inc.	Pt.S1/2 16	6	16.1 (6.5)	20-30 (6-9)	20-30 variable
7	B3-076	Gormley Sand & Gravel Ltd.	SW1/4 22	3	49.5 (20.0)	10-15 (3-5)	10-20
8	A4-159	J. Eek	Pt.N1/2 19*	13*	52.1 (21.1)	15-75 (5-23)	< 20
9	A4-160	J. Eek	Pt.S1/2 10*	14*	10.0 (4.0)	20-30 (6-9)	sand
10	-	The Ontario Jockey Club	SW1/4 4*	14*	41.5 (16.8)	5-12 (1.5-4)	sand
					344.2 (139.3)		
Town of Bradford West Gwillimbury							
11	-	B. Frank	9	10	13.7 (5.5)	10-20 (3-6)	< 30 variable
					13.7 (5.5)		
Total Licenced Area in Report Area:					357.9 (144.8)		
					357.9 (144.8)		
UNLICENCED PITS[1]							
Town of Innisfil							
12	B3-030	DTC (Leslie)	1	11		10-20 (3-6)	10 overgrown
13	-	unknown	7	10		20-30 (6-9)	0-5
14	B3-028	R.A. Flemming	Pt.S1/2 3	8		10-20 (3-6)	< 5
15	-	unknown	3	9		5-15 (1.5-5)	10-20
16	B3-032	unknown	5	9		10 (3)	10-20

TABLE 2. SAND AND GRAVEL PITS, TOWNS OF INNISFIL AND BRADFORD WEST GWILLIMBURY.

1 NO.	2 MTO NO.	3 OWNER/OPERATOR	4 LOT	5 CONC.	6 LICENCED AREAS Acres (Hectares)	7 FACE HEIGHT Feet (Metres)	8 % GRAVEL
17	B3-058	unknown	5	6		5-10 (1.5-3)	< 10 partially overgrown
18	-	unknown	24	13		5-8 (1.5-2)	10-20 partially overgrown
19	-	unknown	23	12		10 (3)	< 10
20	B3-170	Kell	17	11		10-30 (3-9)	< 20 partially overgrown
21	-	unknown	18	11		10 (3)	< 10 overgrown
22	-	unknown	18	10		5-10 (1.5-3)	< 10 partially overgrown
23	-	W.F. Martin	23	12		12 (4)	20
24	B3-001	W.F. Martin	Pt.S1/2 25	12		10-15 (3-5)	20-30 variable
25	B3-001	W.F. Martin	Pt.S1/2 25	12		10-15 (3-5)	20-35 variable
26	B3-002	Black	25	11		5-10 (1.5-3)	20-30 partially overgrown
27	-	unknown	27	10		3 (1)	sand
28	-	unknown	23	8		20-25 (6-8)	< 10 buried
29	-	unknown	25	8		5-10 (1.5-3)	10-20 overgrown
30	-	unknown	25	8		5-8 (1.5-2)	10-20 overgrown
31	B3-023	unknown	22	7		5-10 (1.5-3)	10-20 partially overgrown
32	B3-007	Lamstone Aggr. Supply Ltd.	Pt.N1/2 23	6		10-15 (3-5)	10-30
33	-	Lamstone Aggr. Supply Ltd.	N1/2 23	6		10-15 (3-5)	10
34	B3-131	unknown	21	4		10-20 (3-6)	10-20
35	A4-032	unknown	14,15	3		20 (6)	< 20
36	-	unknown	16,17	3		10 (3)	0-10 partially overgrown

TABLE 2. SAND AND GRAVEL PITS, TOWNS OF INNISFIL AND BRADFORD WEST GWILLIMBURY.

1 NO.	2 MTO NO.	3 OWNER/OPERATOR	4 LOT	5 CONC.	6 LICENCED AREAS Acres (Hectares)	7 FACE HEIGHT Feet (Metres)	8 % GRAVEL
37	B3-146	Todd	21	3		5-10 (1.5-3)	10-20
38	A4-129	unknown	22	2		10-20 (3-6)	10-20
39	-	unknown	21	1		5-10 (1.5-3)	< 10
40	A4-113	unknown	12*	15*		20 (6)	mainly sand overgrown
41	-	unknown	24 formerly Tecumseth	14 Township		10 (3)	variable partially overgrown
42	A4-041	unknown	9*	13*		5 (1.5)	10-20 variable overgrown
43	-	unknown	17*	14*		20-30 (6-9)	till partially overgrown
44	A4-080	unknown	21,22*	13*		5-10 (1.5-3)	till
Town of Bradford West Gwillimbury							
45	-	unknown	19	13		5 (1.5)	20-30
46	-	unknown	17	13		5-10 (1.5-3)	< 20
47	A4-036	Hughes	21	12		5-10 (1.5-3)	20-40
48	A4-116	unknown	21	12		10 (3)	10-20
49	A4-051	unknown	18	12		5 (1.5)	till
50	-	unknown	12	12		5-10 (1.5-3)	mainly sand partially overgrown
51	A4-040	unknown	15	11		5-10 (1.5-3)	< 10
52	A4-130	unknown	16	11		10 (3)	30-40
53	A4-158	Western Escavators	Pt.N1/2 16	10		5-10 (1.5-3)	< 10
54	-	unknown	1	11		10-15 (3-5)	10 partially overgrown
55	A4-108	unknown	8	11		10-15 (3-5)	< 20
56	A4-124	unknown	10	11		6 (2)	< 20

TABLE 2. SAND AND GRAVEL PITS, TOWNS OF INNISFIL AND BRADFORD WEST GWILLIMBURY.

1 NO.	2 MTO NO.	3 OWNER/OPERATOR	4 LOT	5 CONC.	6 LICENCED AREAS Acres (Hectares)	7 FACE HEIGHT Feet (Metres)	8 % GRAVEL
57	A4–103	unknown	6,7	10		10 (3)	< 20 partially overgrown
58	A4–072	MTO	7,8	10		5–20 (1.5–6)	20–50
59	A4–074	unknown	8	10		10–30 (3–9)	30–35 variable
60	–	unknown	10	10		5–20 (1.5–6)	20–30
61	A4–102	Andrews	10	10		5–12 (1.5–4)	overgrown
62	A4–122	unknown	9	9		10 (3)	20–30
63	A4–090	unknown	10	9		5 (1.5)	20 partially overgrown
64	–	unknown	12	9		< 5 (< 1.5)	overgrown
65	A4–011	unknown	11	8		5 (1.5)	< 10 overgrown
66	–	unknown	8	7		10 (3)	till overgrown
67	A4–005	unknown	18	8		5–10 (1.5–3)	overgrown
68	–	unknown	15	5		10–15 (3–5)	10–20
69	–	unknown	15	5		10 (3)	< 10 partially overgrown
70	A4–057	unknown	12	4		40 (12)	till
71	A4–146	Bondomin	11	4		20–30 (6–9)	till
72	–	unknown	7	3		10–15 (3–5)	till overgrown
73	–	unknown	1	2		20–30 (6–9)	till overgrown

* *Lot and concession of the former West Gwillimbury Township.*

[1] *Abandoned pits or wayside pits operating on demand under authority of a permit.*

TABLE 3. SELECTED SAND AND GRAVEL RESOURCE AREAS, TOWNS OF INNISFIL AND BRADFORD WEST GWILLIMBURY.

1 DEPOSIT NO.	2 UNLICENCED AREA Acres (Hectares)	3 CULTURAL SETBACKS Acres (Hectares)	4 EXTRACTED AREA Acres (Hectares)	5 AVAILABLE AREA Acres (Hectares)	6 ESTIMATED DEPOSIT THICKNESS Feet (Metres)	7 AVAILABLE AGGREGATE Millions of Tons (Tonnes)
Town of Innisfil						
1a	173 (70)	47 (19)	69 (28)	57 (23)	15 (5)	2 (2)
1b	260 (105)	75 (30)	45 (18)	140 (57)	15 (5)	5 (4)
	435 (176)	122 (49)	114 (46)	197 (80)		7 (6)
Town of Bradford West Gwillimbury						
2	400 (162)	40 (16)	90 (36)	270 (109)	15 (5)	10 (9)
TOTAL FOR REPORT AREA:						
	840 (340)	162 (66)	204 (83)	465 (188)		17 (15)

TABLE 4. TOTAL IDENTIFIED BEDROCK RESOURCES, TOWNS OF INNISFIL AND BRADFORD WEST GWILLIMBURY.

1 DRIFT THICKNESS Feet (Metres)	2 FORMATION	3 ESTIMATED DEPOSIT THICKNESS Feet (Metres)	4 AREAL EXTENT Acres (Hectares)	5 ORIGINAL TONNAGE Millions of Tons (Tonnes)

- N O N E -

TABLE 5. QUARRIES, TOWNS OF INNISFIL AND BRADFORD WEST GWILLIMBURY.

1 NO.	2 MTO NO.	3 OWNER/ OPERATOR	4 LOT	5 CONC.	6 LICENCED AREA Acres (Hectares)	7 FACE HEIGHT Feet (Metres)

- N O N E -

TABLE 6. SELECTED BEDROCK RESOURCE AREAS, TOWNS OF INNISFIL AND BRADFORD WEST GWILLIMBURY.

1 DEPOSIT NO.	2 DEPTH OF OVERBURDEN Feet (Metres)	3 UNLICENCED AREA Acres (Hectares)	4 CULTURAL SETBACKS Acres (Hectares)	5 EXTRACTED AREA Acres (Hectares)	6 AVAILABLE AREA Acres (Hectares)	7 ESTIMATED WORKABLE THICKNESS Feet (Metres)	8 AVAILABLE RESOURCES Millions of Tons (Tonnes)

- N O N E -

TABLE 7. SUMMARY OF TEST HOLE DATA, TOWNS OF INNISFIL AND BRADFORD WEST GWILLIMBURY

Test Hole Number: WG–TH–1

Location: Lots 1 and 2, Conc. 13, Town of Innisfil (drilled in floor of pit no. 1)

Elevation: Approximately 1025 feet (310 m) asl

Date: November 9, 1982

Depth feet (metres)	Description
20 (6)	clean fine to medium sand

Test Hole Number: WG–TH–2

Location: Lot 1, Conc. 11, Town of Innisfil

Elevation: Approximately 1000 feet (305 m) asl

Date: November 9, 1982

Depth feet (metres)	Description
30 (9)	clean coarse sand and fine gravel, sample no. WG–TH–2 (Figures 2a and 2b)

Test Hole Number: WG–TH–3

Location: Lot 16, Conc. 6, Town of Innisfil (drilled in floor of pit no. 6)

Elevation: Approximately 975 feet (300 m) asl

Date: November 9, 1982

Depth feet (metres)	Description
15 (5)	wet, silty, very fine sand, sample no. WG–TH–3 (Figures 2a and 2b)

Test Hole Number: WG–TH–4

Location: Lots 9 and 10, Conc. 6, Town of Innisfil

Elevation: Approximately 925 feet (280 m) asl

Date: November 9, 1982

Depth feet (metres)	Description
10 (3)	compact sand silt till

Test Hole Number: WG–TH–5

Location: Lot 5, Conc. 5, Town of Innisfil

Elevation: Approximately 975 feet (300 m) asl

Date: November 10, 1982

Depth feet (metres)	Description
10 (3)	sandy silt till

Test Hole Number: WG–TH–5

Location: Lot 4, Conc. 4, Town of Innisfil

Elevation: Approximately 950 feet (290 m) asl

Date: November 10, 1982

Depth feet (metres)	Description
10 (3)	compact sandy silt till

Test Hole Number: WG–TH–6

Location: Lot 6, Conc. 3, Town of Innisfil

Elevation: Approximately 850 feet (260 m) asl

Date: November 10, 1982

Depth feet (metres)	Description
10 (3)	compact sandy silt till

Test Hole Number: WG–TH–8

Location: Lot 12, Conc. 12, Town of Bradford West Gwillimbury

Elevation: Approximately 1000 feet (305 m) asl

Date: July 14, 1982

Depth feet (metres)	Description
40 (12)	clean fine to medium sand, water table encountered at 11 feet (3 m), sample no. WG–TH–7 (Figures 3a and 3b)

Test Hole Number: WG–TH–8

Location: Lot 8, Conc. 10, Town of Bradford West Gwillimbury

Elevation: Approximately 1025 feet (310 m) asl

Date: July 14, 1982

Depth feet (metres)	Description
15 (5)	clean fine to medium sand, water table encountered at 5 feet (1.5 m), sample no. WG–TH–8 (Figures 3a and 3b)

TABLE 8. SUMMARY OF GEOPHYSICS DATA, TOWNS OF INNISFIL AND BRADFORD WEST GWILLIMBURY.

Line Number: WG-GT-1

Line Direction: East to West

Method: Hammer Seismic

Location: Lots 26 and 27, Conc. 1, Town of Innisfil

Elevation: Approximately 775 feet (236 m) asl

Seismic Data:
Number of Layers: 3
Layer Velocities: V_1 = 1900 ft/sec (580 m/s)
V_2 = 2900 ft/sec (880 m/s)
V_3 = 8700 ft/sec (2650 m/s)
Layer Thickness: D1 = 4.5 feet (1.4 m)
D2 = 15.5 feet (4.7 m)

Interpretation: Layer 1: Approx. 5 feet (1.5 m) sand and gravel
Layer 2: Approx. 15 feet (5 m) sand and gravel
Layer 3: till

TABLE 9. RESULTS OF AGGREGATE QUALITY TESTS, TOWNS OF INNISFIL AND BRADFORD WEST GWILLIMBURY.

	COARSE AGGREGATE					FINE AGGREGATE
	Petrographic Number					
Pit No.	GBC & 16 mm Crushed	Hot Mix & Concrete	Magnesium Sulphate Soundness (% Loss)	Absorption (%)	Los Angeles Abrasion (% Loss)	Magnesium Sulphate Soundness (% Loss)

- NONE -

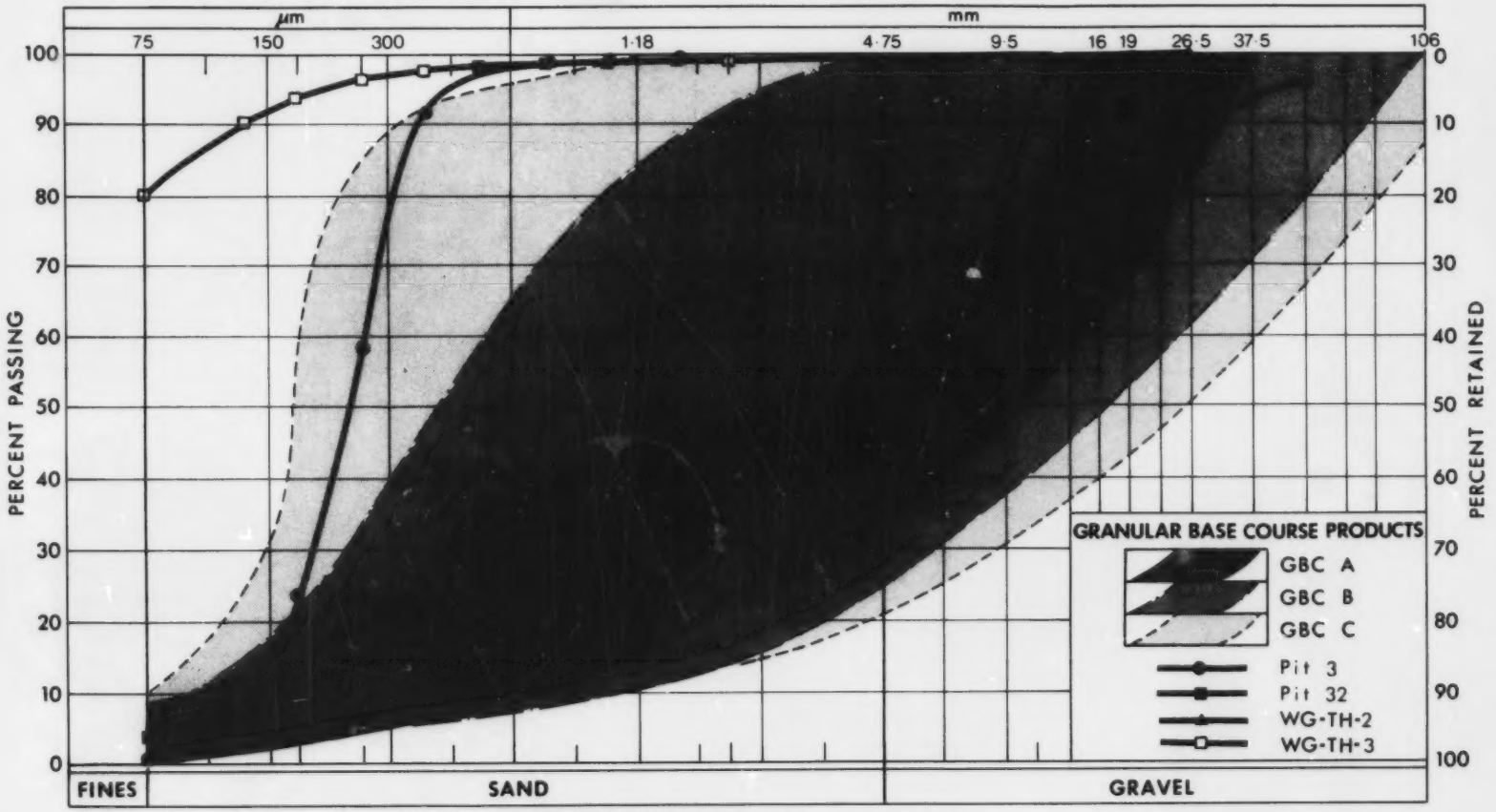


FIGURE 2a. AGGREGATE GRADING CURVES, TOWN OF INNISFIL.

Based on analysis of the total aggregate contained in unprocessed samples (gradation envelopes adapted from M T O Form 1010, 1980).

NOTE:

Information portrayed by grading curves refers strictly to a specific sample at the time of field investigation. Due to the inherent variability of sand and gravel deposits care should be exercised in extrapolating such information to the rest of the deposit.

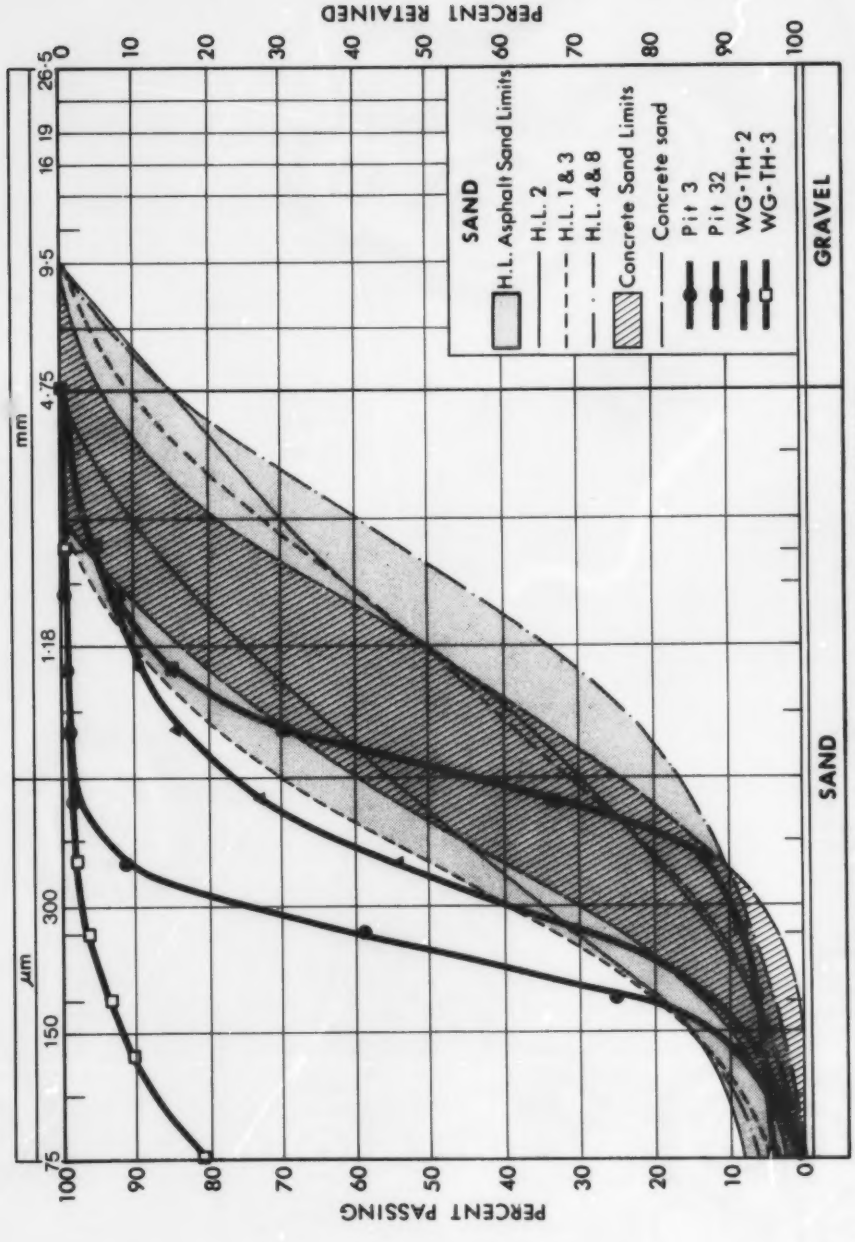


FIGURE 2b. AGGREGATE GRADING CURVES, TOWN OF INNISFIL.

Based on analysis of the sand fraction of the aggregate contained in unprocessed samples (gradation envelopes adapted from M.T.O. Forms 1002, 1979 and 1003, 1981).

NOTE: Information portrayed by grading curves refers strictly to a specific sample at the time of field investigation. Due to the inherent variability of sand and gravel deposits care should be exercised in extrapolating such information to the rest of the deposit.

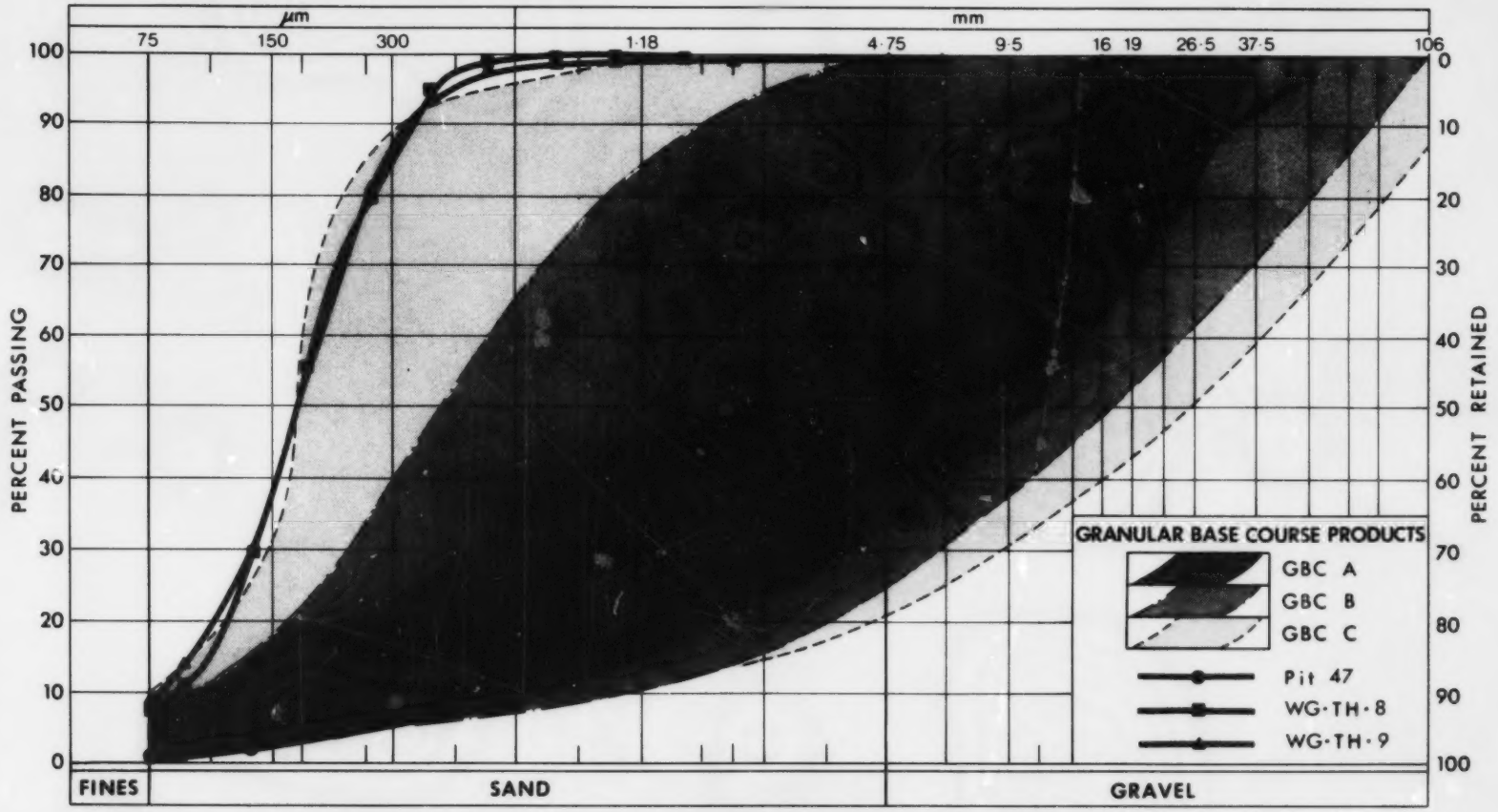


FIGURE 3a. AGGREGATE GRADING CURVES, TOWN OF BRADFORD WEST GWILLIMBURY.

Based on analysis of the total aggregate contained in unprocessed samples (gradation envelopes adapted from M T O Form 1010, 1980).

NOTE:

Information portrayed by grading curves refers strictly to a specific sample at the time of field investigation. Due to the inherent variability of sand and gravel deposits care should be exercised in extrapolating such information to the rest of the deposit.

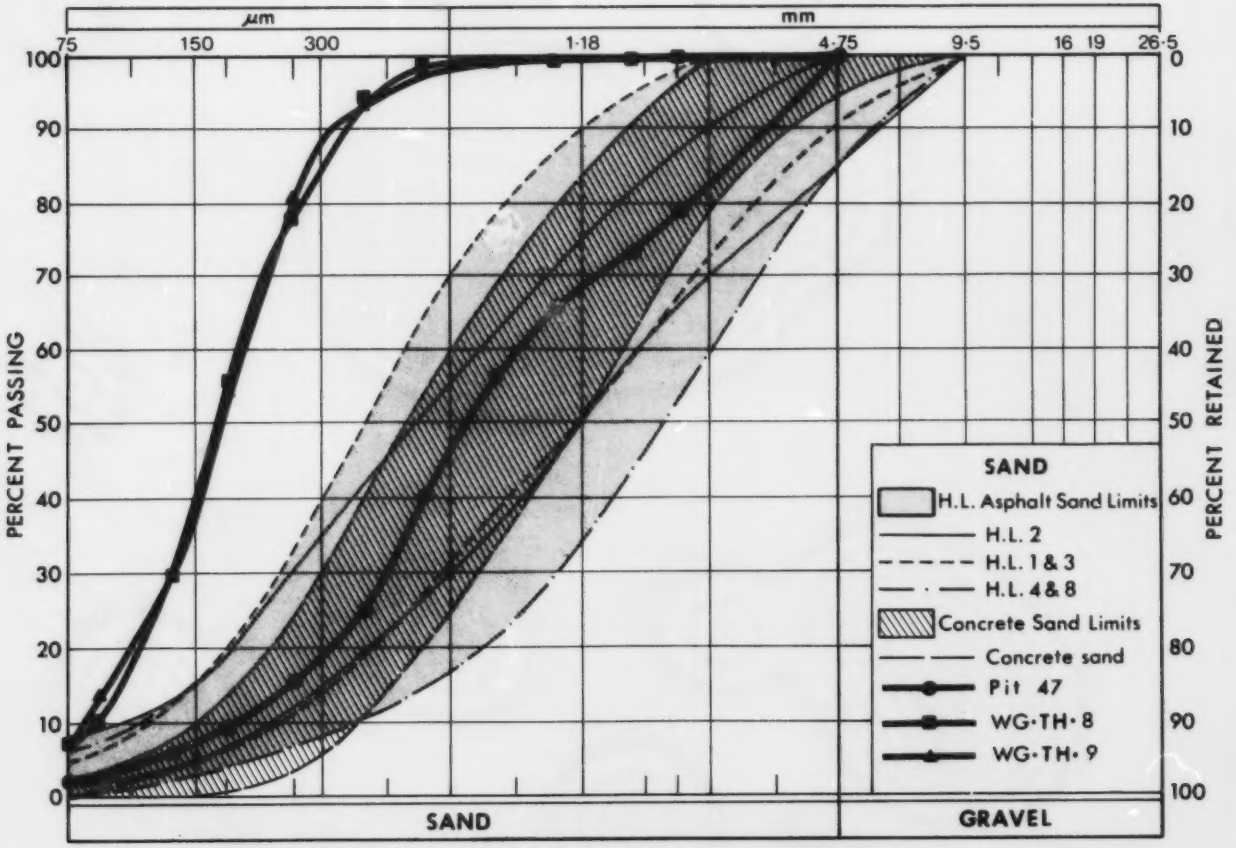


FIGURE 3b. AGGREGATE GRADING CURVES, TOWN OF BRADFORD WEST GWILLIMBURY.

Based on analysis of the sand fraction of the aggregate contained in unprocessed samples (gradation envelopes adapted from M.T.O. Forms 1002, 1979 and 1003, 1981).

NOTE: Information portrayed by grading curves refers strictly to a specific sample at the time of field investigation. Due to the inherent variability of sand and gravel deposits care should be exercised in extrapolating such information to the rest of the deposit.

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Appendix A — Suggested Additional Reading

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Appendix B — Glossary

Abrasion resistance: Tests such as the Los Angeles abrasion test are used to measure the ability of aggregate to resist crushing and pulverizing under conditions similar to those encountered in processing and use. Measuring resistance is an important component in the evaluation of the quality and prospective uses of aggregate. Hard, durable material is preferred for road building.

Absorption capacity: Related to the porosity of the rock types of which an aggregate is composed. Porous rocks are subject to disintegration when absorbed liquids freeze and thaw, thus decreasing the strength of the aggregate.

Aggregate: Any hard, inert, construction material (sand, gravel, shells, slag, crushed stone or other mineral material) used for mixing in various-sized fragments with a cement or bituminous material to form concrete, mortar, etc., or used alone for road building or other construction. Synonyms include mineral aggregate and granular material.

Aggregate Abrasion Value: This test directly measures the resistance of aggregate to abrasion with silica sand and a steel disk. The higher the value, the lower the resistance to abrasion. For high quality asphalt surface course uses, values of less than 6 are desirable.

Alkali-aggregate reaction: A chemical reaction between the alkalis of portland cement and certain minerals found in rocks used for aggregate. Alkali-aggregate reactions are undesirable because they can cause expansion and cracking of concrete. Although perfectly suitable for building stone and asphalt applications, alkali-reactive aggregates should be avoided for structural concrete uses.

Beneficiation: Beneficiation of aggregates is a process or combination of processes which improves the quality (physical properties) of a mineral aggregate and is not part of the normal processing for a particular use, such as routine crushing, screening, washing or classification. Heavy media separation, jigging, or application of special crushers (e.g., "cage mill") are usually considered processes of beneficiation.

Blending: Required in cases of extreme coarseness, fineness, or other irregularities in the gradation of unprocessed aggregate. Blending is done with approved sand-sized aggregate in order to satisfy the gradation requirements of the material.

Bulk Relative Density: An aggregate with low relative density is lighter in weight than one with a high relative density. Low relative density aggregates (less than about 2.5) are often non-durable for many aggregate uses.

Cambrian: The first period of the Paleozoic Era, thought to have covered the time between 570 and 500 million years ago. The Cambrian precedes the Ordovician Period.

Clast: An individual constituent, grain or fragment of a sediment or rock, produced by the mechanical weathering of larger rock mass. Synonyms include particle and fragment.

Crushable aggregate: Unprocessed gravel containing a minimum of 35% coarse aggregate larger than the No. 4 sieve (4.75 mm) as well as a minimum of 20% greater than the 26.5 mm sieve.

Deleterious lithology: A general term used to designate those rock types which are chemically or physically unsuited for use as construction or road-building aggregates. Such lithologies as chert, shale, siltstone and sandstone may deteriorate rapidly when exposed to traffic and other environmental conditions.

Devonian: A period of the Paleozoic Era thought to have covered the span of time between 395 and 345 million years ago, following the Silurian Period. Rocks formed in the Devonian Period are among the youngest found in Ontario.

Dolostone: A carbonate sedimentary rock consisting chiefly of the mineral dolomite and containing relatively little calcite (dolostone is also known as dolomite).

Drift: A general term for all unconsolidated rock debris transported from one place and deposited in another, distinguished from underlying bedrock. In North America, glacial activity has been the dominant mode of transport and deposition of drift. Synonyms include overburden and surficial deposit.

Drumlin: A low, smoothly rounded, elongated hill, mound, or ridge composed of glacial materials. These landforms were formed beneath an advancing ice sheet, and were shaped by its flow.

Eolian: Pertaining to the wind, especially with respect to landforms whose constituents were transported and deposited by wind activity. Sand dunes are an example of an eolian landform.

Fines: A general term used to describe the size fraction of an aggregate which passes (is finer than) the No. 200 mesh screen (0.075 mm). Also described informally as "dirt", these particles are in the silt and clay size range.

Glacial lobe: A tongue-like projection from the margin of the main mass of an ice cap or ice sheet. During the Pleistocene Epoch several lobes of the Laurentide continental ice sheet occupied the Great Lakes basins. These lobes advanced then melted back numerous times during the Pleistocene, producing the complex arrangement of glacial material and landforms found in southern Ontario.

Gradation: The proportion of material of each particle size, or the frequency distribution of the various sizes which constitute a sediment. The strength, durability, permeability and stability of an aggregate depend to a great extent on its gradation. The size limits for different particles are as follows:

Boulder	more than 200 mm
Cobbles	75-200 mm
Coarse Gravel	26.5-75 mm
Fine Gravel	4.75-26.5 mm
Coarse Sand	2-4.75 mm
Medium Sand	0.425-2 mm
Fine Sand	0.075-0.425 mm
Silt, Clay	less than 0.075 mm

Granular base course: Components of the pavement structure of a road, which are placed on the subgrade and are designed to provide strength, stability and drainage, as well as support for surfacing materials. Several types have been defined: Granular Base Course A consists of crushed and processed aggregate and has relatively stringent quality standards in comparison to Granular Base Course B and C which are usually pit-run or other unprocessed aggregate.

Hot-laid (or asphaltic) aggregate: Bituminous, cemented aggregates used in the construction of pavements either as surface or bearing course (HL 1, 3 and 4), or as binder course (HL 2 and 8) used to bind the surface course to the underlying granular base course.

Lithology: The description of rocks on the basis of such characteristics as colour, structure, mineralogic composition and grain size. Generally, the description of the physical character of a rock.

Los Angeles Abrasion and Impact Test: This test measures the resistance to abrasion and the impact strength of aggregate. This gives an idea of the breakdown that can be expected to occur when an aggregate is stockpiled, transported, and placed. Values less than about 35% indicate potentially satisfactory performance for most concrete and asphalt uses. Values of more than 45% indicate that the aggregate may be susceptible to excessive breakdown during handling and placing.

Magnesium sulphate soundness test: This test is designed to simulate the action of freezing and thawing on aggregates. Those aggregates which are susceptible to freezing and thawing will usually break down and give high losses in this test. Values greater than about 12 to 15% indicate potential problems for concrete and asphalt coarse aggregate.

Meltwater channel: A drainage way, often terraced, produced by water flowing away from a melting glacier margin.

Ordovician: An early period of the Paleozoic Era thought to have covered the span of time between 500 and 435 million years ago.

Paleozoic era: One of the major divisions of the geologic time scale thought to have covered the time between 570 and 230 million years ago, the Paleozoic Era (or Ancient Life Era) is subdivided into six geologic periods, of which only four (Cambrian, Ordovician, Silurian and Devonian) can be recognized in southern Ontario.

Petrographic examination: Individual aggregate particles in a sample are divided into categories good, fair, poor, and deleterious, based on their rock type (petrography) and knowledge of past field performance. A petrographic number (PN) is calculated. The higher the PN, the lower the quality of the aggregate.

Pleistocene: An epoch of the recent geological past including the time from approximately 2 million years ago to 7000 years ago. Much of the Pleistocene was characterized by extensive glacial activity and is popularly referred to as the "Great Ice Age".

Polished Stone Value: This test measures the frictional properties of aggregates after 6 hours of abrasion and polishing with an emery abasive. The higher the PSV, the higher the frictional properties of the aggregate. Values less than 45 indicate marginal frictional properties, while values greater than 55 indicate excellent frictional properties.

Possible resource: Reserve estimates based largely on broad knowledge of the geological character of the deposit and for which there are few, if any, samples or measurements. The estimates are based on assumed continuity or repetition for which there are reasonable geological indications.

Precambrian: The earliest geological period extending from the consolidation of the earth's crust to the beginning of the Cambrian.

Shale: A fine-grained, sedimentary rock formed by the consolidation of clay, silt or mud and characterized by well developed bedding planes, along which the rock breaks readily into thin layers. The term shale is also commonly used for fissile claystone, siltstone and mudstone.

Silurian: An early period of the Palezoic Era thought to have covered the time between 435 and 395 million years ago. The Silurian follows the Ordovician Period and precedes the Devonian Period.

Soundness: The ability of the components of an aggregate to withstand the effects of various weathering processes and agents. Unsound lithologies are subject to disintegration caused by the expansion of absorbed solutions. This may seriously impair the performance of road-building and construction aggregates.

Till: Unsorted and unstratified rock debris, deposited directly by glaciers, and ranging in size from clay to large boulders.

Wisconsinan: Pertaining to the last glacial period of the Pleistocene Epoch in North America. The Wisconsinan began approximately 100 000 years ago and ended approximately 7000 years ago. The glacial deposits and landforms of southern Ontario are predominantly the result of glacial activity during the Wisconsinan Stage.

Appendix C — Geology of Sand and Gravel Deposits

The type, distribution, and extent of sand and gravel deposits in southern Ontario are the result of extensive glacial and glacially influenced activity in Wisconsinan time during the Pleistocene Epoch, approximately 100 000 to 7000 years ago. The deposit types reflect the different depositional environments that existed during the melting and retreat of the continental ice masses, and can readily be differentiated on the basis of their morphology, structure, and texture. The deposit types are described below.

GLACIOFLUVIAL DEPOSITS

These deposits can be divided into two broad categories: those that were formed in contact with (or in close proximity to) glacial ice, and those that were deposited by meltwaters carrying materials beyond the ice margin.

Ice-Contact Terraces (ICT): These are glaciofluvial features deposited between the glacial margin and a confining topographic high, such as the side of a valley. The structure of the deposits may be similar to that of outwash deposits, but in most cases the sorting and grading of the material is more variable and the bedding is discontinuous because of extensive slumping. The probability of locating large amounts of crushable aggregate is moderate, and extraction may be expensive because of the variability of the deposits both in terms of quality and grain size distribution.

Kames (K): Kames are defined as mounds of poorly sorted sand and gravel deposited by meltwater in depressions or fissures on the ice surface or at its margin. During glacial retreat, the melting of supporting ice causes collapse of the deposits, producing internal structures characterized by bedding discontinuities. The deposits consist mainly of irregularly bedded and cross-bedded, poorly sorted sand and gravel. The present forms of the deposits include single mounds, linear ridges (crevasse fillings) or complex groups of landforms. The latter are occasionally described as "undifferentiated ice-contact stratified drift" (IC) when detailed subsurface information is unavailable. Since kames commonly contain large amounts of fine-grained material and are characterized by considerable variability, there is generally a low to moderate probability of discovering large amounts of good quality, crushable aggregate. Extractive problems encountered in these deposits are mainly the excessive variability of the aggregate and the rare presence of excess fines (silt- and clay-sized particles).

Eskers (E): Eskers are narrow, sinuous ridges of sand and gravel deposited by meltwaters flowing in tunnels within or at the base of glaciers, or in channels on the ice surface. Eskers vary greatly in size. Many, though not all eskers, consist of a central core of poorly sorted and stratified gravel characterized by a wide range in grain size. The core material is often draped on its flanks by better sorted and stratified gravel. The deposits have a high probability of containing a large proportion of crushable aggregate, and since they are generally built above the surrounding ground surface, are convenient extraction sites. For these reasons esker deposits have been traditional aggregate sources throughout Ontario, and are significant components of the total resources of many areas.

Some planning constraints and opportunities are inherent in the nature of the deposits. Because of their linear nature, the deposits commonly extend across several property boundaries leading to unorganized extractive development at numerous small pits. On the other hand, because of their form, eskers can be easily and inexpensively extracted and are amenable to rehabilitation and sequential land use.

Undifferentiated Ice-Contact Stratified Drift (IC): This designation may include deposits from several ice-contact, depositional environments which usually form extensive, complex landforms. It is not feasible to identify individual areas of coarse-grained material within such deposits because of their lack of continuity and grain size variability. They are given a qualitative rating based on existing pit and other subsurface data.

Outwash (OW): Outwash deposits consist of sand and gravel laid down by meltwaters beyond the margin of the ice lobes. The deposits occur as sheets or as terraced valley fills (valley trains) and may be very large in extent and thickness. Well developed outwash deposits have good horizontal bedding and are uniform in grain size distribution. Outwash deposited near the glacier's margin is much more variable in texture and structure. The probability of locating useful crushable aggregates in outwash deposits is moderate to high depending on how much information on size, distribution and thickness is available.

Subaqueous Fan (SF): Subaqueous fans are formed within or near the mouths of meltwater conduits when sediment laden meltwaters are discharged into a standing body of water. The geometry of the resulting deposit is fan or lobe shaped. Several of these lobes may be joined together to form a larger, continuous sedimentary body. Internally, subaqueous fans consist of stratified sands and gravels which may exhibit wide variations in grain size distribution. As these features were deposited under glacial lake waters, silt and clay which settled out of these lakes may be associated in varying amounts with these deposits. The variability of the sediments and presence of fines are the main extractive problems associated with these deposits.

Alluvium (AL): Alluvium is a general term for clay, silt, sand, gravel, or similar unconsolidated material deposited during postglacial time by a stream as sorted or semi-sorted sediment, on its bed or on its floodplain. The probability of locating large amounts of crushable aggregate in alluvial deposits is low, and they have gen-

erally low value because of the presence of excess silt- and clay-sized material. There are few large postglacial alluvium deposits in Ontario.

GLACIOLACUSTRINE DEPOSITS

Glaciolacustrine Beach Deposits (LB): These are relatively narrow, linear features formed by wave action at the shores of glacial lakes that existed at various times during the deglaciation of southern Ontario. Well developed lacustrine beaches are usually less than 20 feet (6 m) thick. The aggregate is well sorted and stratified and sand-sized material commonly predominates. The composition and size distribution of the deposit depends on the nature of the source material. The probability of obtaining crushable aggregate is high when the material is developed from coarse-grained materials such as a stony till, and low when developed from fine-grained materials. Beaches are relatively narrow, linear deposits, so that extractive operations are often numerous and extensive.

Glaciolacustrine Deltas (LD): These features were formed where streams or rivers of glacial meltwater flowed into lakes and deposited their suspended sediment. In southern Ontario such deposits tend to consist mainly of sand and abundant silt. However, in near-ice and ice-contact positions, coarse material may be present. Although deltaic deposits may be large, the probability of obtaining coarse material is generally low.

Glaciolacustrine Plains (LP): The nearly level surface marking the floor of an extinct glacial lake. The sediments which form the plain are predominantly fine to medium sand, silt, and clay, and were deposited in relatively deep water. Lacustrine deposits are generally of low value as aggregate sources because of their fine grain size and lack of crushable material. In some aggregate-poor areas, lacustrine deposits may constitute valuable sources of fill and some granular base course aggregate.

GLACIAL DEPOSITS

End Moraines (EM): These are belts of glacial drift deposited at, and parallel to, glacier margins. End moraines commonly consist of ice-contact stratified drift and in such instances are usually called kame moraines. Kame moraines commonly result from deposition between two glacial lobes (interlobate moraines). The probability of locating aggregates within such features is moderate to low. Exploration and development costs are high. Moraines may be very large and contain vast aggregate resources, but the location of the best areas within the moraine is usually poorly defined.

EOLIAN DEPOSITS

Windblown Deposits (WD): Windblown deposits are those formed by the transport and deposition of sand by winds. The form of the deposits ranges from extensive, thin layers to well developed linear and crescentic ridges known as dunes. Most windblown deposits in southern Ontario are derived from, and deposited on, pre-existing lacustrine sand plain deposits. Windblown sediments almost always consist of fine to coarse sand and are usually well sorted. The probabiltiy of locating crushable aggregate in windblown deposits is very low.

Appendix D — Geology of Bedrock Deposits

The purpose of this appendix is to familiarize the reader with the general bedrock geology of southern Ontario (Figure D1), and the potential uses of the various bedrock formations where known. The reader is cautioned against using this information for more specific purposes. The stratigraphic chart (Figure D2) is intended only to illustrate the stratigraphic sequences in particular geographic areas and should not be used as a regional correlation table.

The following description is arranged in ascending stratigraphic order, on a group and formation basis. Precambrian rocks are not discussed. Additional stratigraphic information is included for some formations where necessary. The publications and maps of the Ontario Geological Survey and the Geological Survey of Canada should be referred to for more detailed information. The composition, thickness, and uses of the formations are discussed. If a formation may be suitable for use as aggregate and aggregate suitability test data is available, the data has been included in the form of ranges. The following short forms have been used in presenting this data: PSV = Polished Stone Value, AAV = Aggregate Abrasion Value, $MgSO_4$ = Magnesium Sulphate Soundness Test (loss in percent), LA = Los Angeles Abrasion and Impact Test (loss in percent), Absn = Absorption (percent), BRD = Bulk Relative Density, PN (Asphalt & Concrete) = Petrographic Number for Asphalt and Concrete use.

The ranges are intended as a guide only and care should be exercised in extrapolating the information to specific situations. Aggregate suitability test data has been provided by the Ontario Ministry of Transportation.

Covey Hill Formation (Cambrian)

STRATIGRAPHY: lower formation of the Potsdam Group. COMPOSITION: interbedded non-calcareous feldspathic conglomerate and sandstone. THICKNESS: 0 to 45 feet (0 to 14 m). USES: has been quarried for aggregate in South Burgess Township, Leeds County.

Nepean Formation (Cambro-Ordovician)

STRATIGRAPHY: upper formation of the Potsdam Group. COMPOSITION: thin-bedded to massive quartz sandstone with some conglomerate interbeds and rare shaly partings. THICKNESS: 0 to 100 feet (0 to 30 m). USES: suitable as dimension stone; quarried at Philipsville and Forfar for silica sand; alkali-silica reactive in Portland cement concrete. AGGREGATE SUITABILITY TESTING: PSV = 54-68, AAV = 4-15, $MgSO_4$ = 9-32, LA = 44-90, Absn = 1.6-2.6, BRD = 2.38-2.50, PN (Asphalt & Concrete) = 130-140.

March Formation (Lower Ordovician)

STRATIGRAPHY: lower formation of the Beekmantown Group. COMPOSITION: interbedded quartz sandstone, dolomitic quartz sandstone, sandy dolostone and dolostone. THICKNESS: 60 to 197 feet (18 to 60 m). USES: quarried extensively for aggregate in area of subcrop and outcrop; alkali-silica reactive in Portland cement concrete; lower part of formation is an excellent source of skid-resistant aggregate; suitable for use as facing stone and paving stone. AGGREGATE SUITABILITY TESTING: PSV = 55-60, AAV = 4-6, $MgSO_4$ = 1-17, LA = 15-38, Absn = 0.5-0.9, BRD = 2.61-2.65, PN (Asphalt & Concrete) = 110-150.

Oxford Formation (Lower Ordovician)

STRATIGRAPHY: upper formation of the Beekmantown Group. COMPOSITION: thin- to thick-bedded, microcrystalline to medium-crystalline, grey dolostone with thin shaly interbeds. THICKNESS: 200 to 335 feet (61 to 102 m). USES: quarried in the Brockville and Smith Falls areas and south of Ottawa for use as aggregate. AGGREGATE SUITABILITY TESTING: PSV = 47-48, AAV = 7-8, $MgSO_4$ = 1-4, LA = 18-23, Absn = 0.7-0.9, BRD = 2.74-2.78, PN (Asphalt & Concrete) = 105-120.

Rockcliffe Formation (Middle Ordovician)

STRATIGRAPHY: divided into lower member and upper (St. Martin) member. COMPOSITION: interbedded quartz sandstone and shale; interbedded shaly bioclastic limestone and shale predominating in upper member to the east. THICKNESS: 0 to 410 feet (0 to 125 m). USES: upper member has been quarried east of Ottawa for aggregate; lower member has been used as crushed stone; some high purity limestone beds in upper member may be suitable for use as fluxing stone and in lime production. AGGREGATE SUITABILITY TESTING: PSV = 58-63, AAV = 10-11, $MgSO_4$ = 12-40, LA = 25-28, Absn = 1.8-1.9, BRD = 2.55-2.62, PN (Asphalt & Concrete) = 122-440.

Shadow Lake Formation (Middle Ordovician)

STRATIGRAPHY: eastern Ontario - the basal unit of the Ottawa Group; central Ontario - overlain by the Simcoe Group. COMPOSITION: in eastern Ontario - silty and sandy dolostone with shale partings and minor interbeds of sandstone; in central Ontario - conglomer-

ates, sandstones, and shales. THICKNESS: eastern Ontario - 7 to 10 feet (2 to 3 m); central Ontario - 0 to 40 feet (0 to 12 m). USES: potential source of decorative stone; very limited value as aggregate source.

Gull River Formation (Middle Ordovician)

STRATIGRAPHY: part of the Simcoe Group (central Ontario) and Ottawa Group (eastern Ontario). In central and eastern Ontario the formation is subdivided into upper and lower members; west of Lake Simcoe it is presently subdivided into upper, middle and lower members. COMPOSITION: in central and eastern Ontario the lower member consists of alternating units of limestone, dolomitic limestone, and dolostone, the upper member consists of thin-bedded limestones with thin shale partings; west of Lake Simcoe the lower member is thin- to thick-bedded, interbedded, grey argillaceous limestone and buff to green dolostone, whereas the upper and middle members are dense microcrystalline limestones with argillaceous dolostone interbeds. THICKNESS: 23 to 204 feet (7 to 62 m). USES: quarried in the Lake Simcoe, Kingston, Ottawa, and Cornwall areas for crushed stone; rock from certain layers in eastern and central Ontario has proven to be alkali-reactive when used in Portland cement concrete (alkali-carbonate reaction). AGGREGATE SUITABILITY TESTING: PSV = 41-49, AAV = 8-12, $MgSO_4$ = 3-13, LA = 18-28, Absn = 0.3-0.9, BRD = 2.68-2.73, PN (Asphalt & Concrete) = 100-153.

Bobcaygeon Formation (Middle Ordovician)

STRATIGRAPHY: part of the Simcoe Group (central Ontario) and the Ottawa Group (eastern Ontario), subdivided into upper, middle and lower members; members in eastern and central Ontario are approximately equivalent. COMPOSITION: homogeneous, massive to thin-bedded fine-crystalline limestone with numerous shaly partings in the middle member. THICKNESS: 80 to 285 feet (24 to 87 m). USES: quarried at Brechin, Marysville, and in the Ottawa area for crushed stone; generally suitable for use as granular base course aggregate; rock from certain layers has been found to be alkali-reactive when used in Portland cement concrete (alkali-silica reaction). AGGREGATE SUITABILITY TESTING: PSV = 47-51, AAV = 14-23, $MgSO_4$ = 1-40, LA = 18-32, Absn = 0.3-2.4, BRD = 2.5-2.69, PN (Asphalt & Concrete) = 100-320.

Verulam Formation (Middle Ordovician)

STRATIGRAPHY: part of Simcoe and Ottawa Groups. COMPOSITION: fossiliferous, pure to argillaceous limestone interbedded with calcareous shale. THICKNESS: 105 to 230 feet (32 to 70 m). USES: quarried at Picton and Bath for use in cement manufacture; quarried for aggregate in Mara Township, Simcoe County and in the Belleville-Kingston area; may be unsuitable for use as aggregate in some areas because of its high shale content. AGGREGATE SUITABILITY TESTING: PSV = 43-44, AAV = 9-13, $MgSO_4$ = 4-45, LA = 22-29, Absn = 0.4-2.1, BRD = 2.59-2.70, PN (Asphalt & Concrete) = 120-255.

Lindsay Formation (Middle and Upper Ordovician)

STRATIGRAPHY: part of Simcoe and Ottawa Groups; in eastern Ontario is divisible into an unnamed lower member and the Eastview Member; in central Ontario is divisible into the Collingwood Member (equivalent to portions of the Eastview Member) and a lower member. COMPOSITION: in eastern Ontario the lower member is interbedded, very fine- to coarse-crystalline limestone with undulating shale partings and interbeds of dark grey calcareous shale, whereas the Eastview Member is an interbedded dark grey to dark brown calcareous shale and very fine- to fine-crystalline, petroliferous limestone; in central Ontario Collingwood Member is a black, calcareous shale whereas the lower member is a very fine- to coarse-crystalline, thin-bedded limestone with very thin, undulating shale partings. THICKNESS: 82 to 200 feet (25 to 61 m). USES: in eastern Ontario the lower member is used extensively for aggregate production; in central Ontario it is quarried at Picton, Ogden Point and Bowmanville for cement; may be suitable or unsuitable for use as concrete and asphalt aggregate. AGGREGATE SUITABILITY TESTING: $MgSO_4$ = 2-47, LA = 20-28, Absn = 0.4-1.3, BRD = 2.64-2.70, PN (Asphalt & Concrete) = 110-215.

Blue Mountain and Billings Formations (Upper Ordovician)

STRATIGRAPHY: central Ontario - Blue Mountain Formation includes the upper and middle members of the former Whitby Formation; eastern Ontario - Billings Formation is equivalent to part of the Blue Mountain Formation. COMPOSITION: the Blue Mountain Formation is blue-grey, noncalcareous shale; Billings Formation is dark grey to black, noncalcareous to slightly calcareous, pyritiferous shale with dark grey limestone laminae and grey siltstone interbeds. THICKNESS: Blue Mountain Formation - 140 to 200 feet (43 to 61 m); Billings Formation - 0 to 205 feet (0 to 62 m). USES: Billings Formation may be a suitable source for structural clay products and expanded aggregate; Blue Mountain Formation may be suitable for structural clay products.

Georgian Bay and Carlsbad Formations (Upper Ordovician)

COMPOSITION: in central Ontario the Georgian Bay Formation is composed of interbedded limestone and shale; in eastern Ontario the Carlsbad Formation is composed of interbedded shale, siltstone and bioclastic limestone; THICKNESS: Georgian Bay Formation is 300 to 560 feet (91 to 170 m); Carlsbad Formation - 0 to 610 feet (0 to 186 m). USES: Georgian Bay Formation is

used by several producers in Metropolitan Toronto area to produce brick and structural tile, as well as for making Portland cement; at Streetsville, expanded shale was used in the past to produce lightweight aggregate; Carlsbad Formation is used as a source material for brick and tile manufacturing, has potential as a lightweight expanded aggregate.

Queenston Formation (Upper Ordovician)

COMPOSITION: red, thin- to thick-bedded, sandy to argillaceous shale with green mottling and banding. THICKNESS: 400 to 500 feet (122 to 152 m). USES: there are several large quarries developed in the Queenston Formation in the Toronto-Hamilton region and one at Russell, near Ottawa; all extract shale for brick manufacturing; the Queenston Formation is the most important source material for brick manufacture in Ontario.

Whirlpool Formation (Lower Silurian)

STRATIGRAPHY: lower formation in the Cataract Group in the Niagara Penninsula and the Niagara Escarpment as far north as Duntroon. COMPOSITION: massive, medium- to coarse-grained, argillaceous white to light grey quartz sandstone with thin grey shale partings. THICKNESS: 0 to 25 feet (0 - 8 m). USES: building stone, flagstone.

Manitoulin Formation (Lower Silurian)

STRATIGRAPHY: part of the Cataract Group, occurs north of Stoney Creek. COMPOSITION: thin-bedded, blue-grey to buff-brown dolomitic limestones and dolostones. THICKNESS: 0 to 75 feet (0 to 23 m). USES: extracted for crushed stone in St. Vincent Township, Grey County, and for decorative stone on Manitoulin Island. AGGREGATE SUITABILITY TESTING: no data.

Cabot Head Formation (Lower Silurian)

STRATIGRAPHY: part of the Cataract Group, occurs throughout southern Ontario, south and north of the Niagara Escarpment. COMPOSITION: green, grey and red shales. THICKNESS: 50 to 60 feet (15 to 18 m); USES: potential source of coated lightweight aggregate and raw material for use in manufacture of brick and tile; lack of suitable exposures has limited its use.

Grimsby Formation

STRATIGRAPHY: upper formation of the Cataract Group, is identified on the Niagara Peninsula as far north as Clappison's Corners. COMPOSITION: interbedded sandstone and shale, mostly red. THICKNESS: 0 to 50 feet (0 to 15 m). USES: no present uses.

Thorold Formation (Middle Silurian)

STRATIGRAPHY: lower formation in the Clinton Group on the Niagara Peninsula. COMPOSITION: thick-bedded quartz sandstone. THICKNESS: 7 to 10 feet (2 - 3 m). USES: no present uses.

Neagha Formation (Middle Silurian)

STRATIGRAPHY: part of the Clinton Group on the Niagara Peninsula. COMPOSITION: dark grey to green shale with minor interbedded limestone. THICKNESS: 0 to 5 feet (0 to 2 m). USES: no present uses.

Dyer Bay Formation (Middle Silurian)

STRATIGRAPHY: lower formation in the Clinton Group on Manitoulin Island and northernmost Bruce Peninsula. COMPOSITION: highly fossiliferous, impure dolostone. THICKNESS: 0 to 20 feet (0 to 6 m). USES: no present uses.

Wingfield Formation (Middle Silurian)

STRATIGRAPHY: part of the Clinton Group on Manitoulin Island and northernmost Bruce Peninsula. COMPOSITION: olive green to grey shale with dolostone interbeds. THICKNESS: 0 to 36 feet (0 to 11 m). USES: no present uses.

St. Edmund Formation (Middle Silurian)

STRATIGRAPHY: part of the Clinton Group on Manitoulin Island and northernmost Bruce Peninsula, upper portion previously termed the Mindemoya Formation. COMPOSITION: pale grey to buff brown, micro- to medium-crystalline, thin- to medium-bedded dolostone. THICKNESS: 0 to 85 feet (0 to 26 m). USES: quarried for fill and crushed stone on Manitoulin Island. AGGREGATE SUITABILITY TESTING: $MgSO_4$ = 1-2, LA = 19-21, Absn = 0.6-0.7, BRD = 2.78-2.79, PN (Asphalt & Concrete) = 105.

Fossil Hill and Reynales Formations (Middle Silurian)

STRATIGRAPHY: part of Clinton Group; Fossil Hill Formation occurs in the northern part of the Niagara Escarpment and is approximately equivalent in part, to the Reynales Formation which occurs on the Niagara Peninsula and the Escarpment, as far north as the Forks of the Credit. COMPOSITION: Fossil Hill Formation is fine- to coarse-crystalline dolostone with high silica content; Reynales Formation is thin- to thick-bedded shaly dolostone and dolomitic limestone. THICKNESS: Fossil Hill Formation - 20 to 85 feet (6 to 26 m); Reynales Formation - 0 to 10 feet (0 to 3 m). USES: both formations quarried for aggregate with overlying Amabel and Lockport Formations. AGGREGATE SUITABILITY TESTING: (Fossil Hill Formation on Manitoulin Island) $MgSO_4$ = 41, LA = 29, Absn = 4.1, BRD = 2.45, PN (Asphalt & Concrete) = 370.

Irondequoit Formation (Middle Silurian)

STRATIGRAPHY: part of Clinton Group on the Niagara Peninsula south of Waterdown. COMPOSITION: massive, coarse-crystalline crinoidal limestone. THICKNESS: 0 to 7 feet (0 to 2 m). USES: not significantly utilized.

Rochester Formation (Middle Silurian)

STRATIGRAPHY: part of Clinton Group along the Niagara Peninsula. COMPOSITION: black to dark grey calcareous shale with numerous limestone lenses. THICKNESS: 15 to 60 feet (5 to 18 m). USES: not significantly utilized. AGGREGATE SUITABILITY TESTING: PSV = 69, AAV = 17, $MgSO_4$ = 95, LA = 19, Asbn = 2.2, BRD = 2.67, PN (Asphalt & Concrete) = 400.

Decew Formation (Middle Silurian)

STRATIGRAPHY: part of Clinton Group south of Waterdown along the Niagara Peninsula. COMPOSITION: sandy to shaly dolomitic limestone and dolostone. THICKNESS: 0 to 15 feet (0 to 5 m). USES: too shaly for high quality uses, but is quarried along with Lockport Formation in places. AGGREGATE SUITABILITY TESTING: PSV = 67, AAV = 15, $MgSO_4$ = 55, LA = 21, Absn = 2.2, BRD = 2.66, PN (Asphalt & Concrete) = 255.

Lockport and Amabel Formations (Middle Silurian)

STRATIGRAPHY: Lockport Formation occurs from Waterdown to Niagara Falls, subdivided into 3 formal members: Gasport, Goat Island and Eramosa Members and an informal member (the "Vinemount shale beds"); the stratigraphically equivalent Amabel Formation, found from Waterdown to Cockburn Island, is subdivided into Lions Head, Wiarton/Colpoy Bay, and Eramosa members. COMPOSITION: Lockport Formation is thin- to massive-bedded, fine- to medium-crystalline dolostone; Amabel Formation is thin bedded to massive, medium-crystalline dolostone with reef facies near Georgetown and on the Bruce Peninsula. THICKNESS: (Lockport/ Amabel) 10 to 130 feet (3 to 40 m). USES: both formations have been used to produce lime, crushed stone, concrete aggregate, and building stone throughout their area of occurrence, and are a resource of provincial significance. AGGREGATE SUITABILITY TESTING: PSV = 36-49, AAV = 10-17, $MgSO_4$ = 2-6, LA = 25-32, Absn = 0.4-1.54, BRD = 2.61-2.81, PN (Asphalt & Concrete) = 100-105.

Guelph Formation (Middle Silurian)

STRATIGRAPHY: exposed on the Niagara Escarpment from the Niagara River to the tip of the Bruce Peninsula, mostly present in the subsurface of southwestern Ontario. COMPOSITION: micro-crystalline to medium-crystalline, thick-bedded, soft, porous dolostone, characterized in places by extensive vuggy, porous reefal facies of high chemical purity. THICKNESS: 100 to 170 feet (30 to 52 m). USES: some areas appear soft and unsuitable for use in the production of load-bearing aggregate; this unit requires additional testing to fully establish its aggregate suitability; main use is for dolomitic lime for cement manufacture; quarried near Hamilton and Guelph.

Salina Formation (Upper Silurian)

STRATIGRAPHY: present in the subsurface of southwestern Ontario; rarely exposed at the surface. COMPOSITION: grey and maroon shale, brown dolostone and, in places, salt, anhydrite and gypsum; consists predominantly of evaporitic rich material with up to eight units identifiable. THICKNESS: 370 to 600 feet (113 to 183 m). USES: gypsum mines at Hagersville, Caledonia, and Drumbo; salt is mined at Goderich and Windsor, and is produced from brine wells at Amherstburg, Windsor and Sarnia.

Bertie and Bass Islands Formations (Upper Silurian)

STRATIGRAPHY: Bertie Formation found in southern Niagara Peninsula; Bass Islands Formation, the Michigan Basin equivalent of the Bertie Formation, does not significantly outcrop in Ontario but is present in the subsurface in southwestern Ontario; Bertie Formation represented by Oatka, Falkirk, Scajaquanda, Williamsville, and Akron Members. COMPOSITION: medium- to massive-bedded, micro-crystalline, brown dolostone with shaly partings. THICKNESS: 45 to 160 feet (14 to 49 m). USES: quarried for crushed stone on the Niagara Peninsula at Fort Erie, Cayuga, Hagersville and Dunnville; shaly intervals are unsuitable for use as high specification aggregate because of low freeze-thaw durability; has also been extracted for lime. AGGREGATE SUITABILITY TESTING: PSV = 46-49, AAV = 8-11, $MgSO_4$ = 4-19, LA = 14-23, Absn = 0.8-2.8, BRD = 2.61-2.78, PN (Asphalt & Concrete) = 102-120.

Oriskany Formation (Lower Devonian)

STRATIGRAPHY: basal Devonian clastic unit, found in Niagara Peninsula. COMPOSITION: thick- to massive-bedded, coarse-grained, grey-yellow sandstone. THICKNESS: 0 to 15 feet (0 to 5 m). USES: has been quarried for silica sand, building stone, and armour stone; may be acceptable for use as rip rap, and well cemented varieties may be acceptable for some asphaltic products. AGGREGATE SUITABILITY TESTING: (of a well cemented variety of the formation) PSV = 64, AAV = 6, $MgSO_4$ = 2, LA = 29, Absn = 1.2-1.3, BRD = 2.55, PN (Asphalt & Concrete) = 107.

Bois Blanc Formation (Lower Devonian)

STRATIGRAPHY: Springvale Sandstone Member forms the lower portion of formation. COMPOSI-

TION: a cherty limestone with shale partings and minor interbedded dolostones; Springvale Sandstone Member is a medium- to coarse-grained, green glauconitic sandstone with interbeds of limestone, dolostone and brown chert. THICKNESS: 10 to 130 feet (3 to 40 m). USES: quarried at Hagersville, Cayuga, and Port Colborne for crushed stone; material generally unsuitable for concrete aggregate because of high chert content. AGGREGATE SUITABILITY TESTING: PSV = 48-53, AAV = 3-7, $MgSO_4$ = 3-18, LA = 15-22, Absn = 1.3-2.8, BRD = 2.50-2.70, PN (Asphalt & Concrete) = 102-290.

Onondaga Formation (Middle Devonian)

STRATIGRAPHY: correlated to part of the Detroit River Group; occurs on the Niagara Peninsula from Simcoe to Niagara Falls; contains the Edgecliff, Clarence, and Moorehouse Members. COMPOSITION: medium-bedded, fine- to coarse-grained, dark grey-brown or purplish-brown, variably cherty limestone. THICKNESS: 60 to 82 feet (18 to 25 m) USES: quarried for crushed stone on the Niagara Peninsula at Welland and Port Colborne; high chert content makes much of the material unsuitable for use as concrete aggregate and asphaltic concrete; has been used as a raw material in cement manufacture. AGGREGATE SUITABILITY TESTING: (Clarence and Edgecliff Members) $MgSO_4$ = 1-6, LA = 16.8-22.4, Absn = 0.5-1.1, PN (Asphalt & Concrete) = 190-276.

Amherstburg Formation (Middle Devonian)

STRATIGRAPHY: part of Detroit River Group; correlated to Onondaga Formation in Niagara Penninsula; contains Sylvania Sandstone Member and Formosa Reef Limestone. COMPOSITION: bituminous, bioclastic, stromatoporoid-rich limestone and dolostone with grey chert nodules; Formosa Reef Limestone is high purity (calcium rich) limestone; Sylvania Sandstone Member is quartz sandstone. THICKNESS: 0 to 165 feet (0 to 50 m); Formosa Reef Limestone up to 85 feet (26 m). USES: cement manufacture, agricultural lime, aggregate. AGGREGATE SUITABILITY TESTING: PSV = 57, AAV = 19, $MgSO_4$ = 9-35, LA = 26-52, Absn = 1.1-6.4, BRD = 2.35-2.62, PN (Asphalt & Concrete) = 105-300.

Lucas Formation (Middle Devonian)

STRATIGRAPHY: part of the Detroit River Group in southwestern Ontario; includes the Anderdon Member which, in the Woodstock Beachville area, may constitute the bulk of the formation. COMPOSITION: light brown or grey-brown dolostone with bituminous laminations and minor chert; Anderdon Member consists of very high purity (calcium-rich) limestone. THICKNESS: 130 to 246 feet (40 to 75 m). USES: most important source of high-purity limestone in Ontario; used as calcium lime for metallurgical flux and for the manufacture of chemicals; rock of lower purity is used for cement manufacture, agricultural lime and aggregate; Anderdon Member is quarried at Amherstburg for crushed stone. AGGREGATE SUITABILITY TESTING: PSV = 46-47, AAV = 15-16, $MgSO_4$ = 2-60, LA = 22-47, Absn = 1.1-6.5, BRD = 2.35-2.40, PN (Asphalt & Concrete) = 110-160.

Dundee Formation (Middle Devonian)

STRATIGRAPHY: few natural outcrops, largely in the subsurface of southwestern Ontario. COMPOSITION: fine- to medium-crystalline, brownish-grey, medium- to thick-bedded, dolomitic limestone with shaly partings sandy layers, and chert in some areas. THICKNESS: 50 to 100 feet (15 to 30 m). USES: quarried near Port Dover and on Pelee Island for crushed stone; used at St. Marys as a raw material for Portland cement. AGGREGATE SUITABILITY TESTING: $MgSO_4$ = 1-28, LA = 22-46, Absn = 0.6-6.8, PN (Asphalt & Concrete) = 125-320.

Marcellus Formation (Middle Devonian)

STRATIGRAPHY: subsurface unit, mostly found below Lake Erie and extending into the eastern U.S.A., pinches out in the Port Stanley area. COMPOSITION: black, bituminous shales. THICKNESS: 0 to 15 feet (0 to 5 m). USES: no present uses.

Bell Formation (Middle Devonian)

STRATIGRAPHY: lowest formation of the Hamilton Group, no outcrop in Ontario. COMPOSITION: soft blue and grey calcareous shale. THICKNESS: 0 to 30 feet (0 to 9 m). USES: no present uses.

Rockport Quarry Formation (Middle Devonian)

STRATIGRAPHY: part of the Hamilton Group; no outcrop in Ontario. COMPOSITION: grey-brown, very fine-grained limestone with occasional shale layers. THICKNESS: 0 to 20 feet (0 to 6 m). USES: no present uses.

Arkona Formation (Middle Devonian)

STRATIGRAPHY: part of the Hamilton Group. COMPOSITION: blue-grey, plastic, clay shale with occasional thin and laterally discontinuous limestone lenses. THICKNESS: 15 to 120 feet (5 to 37 m). USES: has been extracted at Thedford and near Arkona for the production of drainage tile.

Hungry Hollow Formation (Middle Devonian)

STRATIGRAPHY: part of the Hamilton Group. COMPOSITION: grey crinoidal limestone and soft, fossiliferous calcareous shale. THICKNESS: 0 to 6 feet (0 to 2 m). USES: suitable for some crushed stone and fill with selective quarrying. AGGREGATE SUITABILITY TESTING: No data.

Widder Formation (Middle Devonian)

STRATIGRAPHY: part of the Hamilton Group. COMPOSITION: mainly soft, grey, fossiliferous calcareous shale interbedded with blue-grey, fine-grained fossiliferous limestone. THICKNESS: 0 to 45 feet (0 to 14 m). USES: no present uses.

Ipperwash Formation (Middle Devonian)

STRATIGRAPHY: upper formation of the Hamilton Group; very limited distribution. COMPOSITION: medium- to coarse-grained, grey-brown, bioclastic limestone. THICKNESS: 5 to 45 feet (2-14 m). USES: no present uses.

Kettle Point Formation (Upper Devonian)

STRATIGRAPHY: occurs in a band between Sarnia and Erieau; small part overlain by Port Lambton Group rocks in extreme northwest. COMPOSITION: black, highly fissile, organic-rich shale with minor interbeds of grey-green silty shale. THICKNESS: 0 to 200 feet (0 to 61 m). USES: possible source of fill; possible source of material for use as sintered lightweight aggregate.

Bedford Formation (Upper Devonian)

STRATIGRAPHY: lower formation of the Port Lambton Group. COMPOSITION: soft, grey shale. THICKNESS: 0 to 108 feet (0 to 33 m). USES: no present uses.

Berea Formation (Upper Devonian)

STRATIGRAPHY: middle formation of the Port Lambton Group; not known to occur at surface in Ontario. COMPOSITION: grey, fine- to medium-grained sandstone, often dolomitic and interbedded with grey shale and siltstone. THICKNESS: 0 to 197 feet (0 to 60 m). USES: no present uses.

Sunbury Formation (Upper Devonian)

STRATIGRAPHY: upper formation of the Port Lambton Group; not known to occur at surface in Ontario. COMPOSITION: black shale. THICKNESS: 0 to 66 feet (0 to 20 m). USES: no present uses.

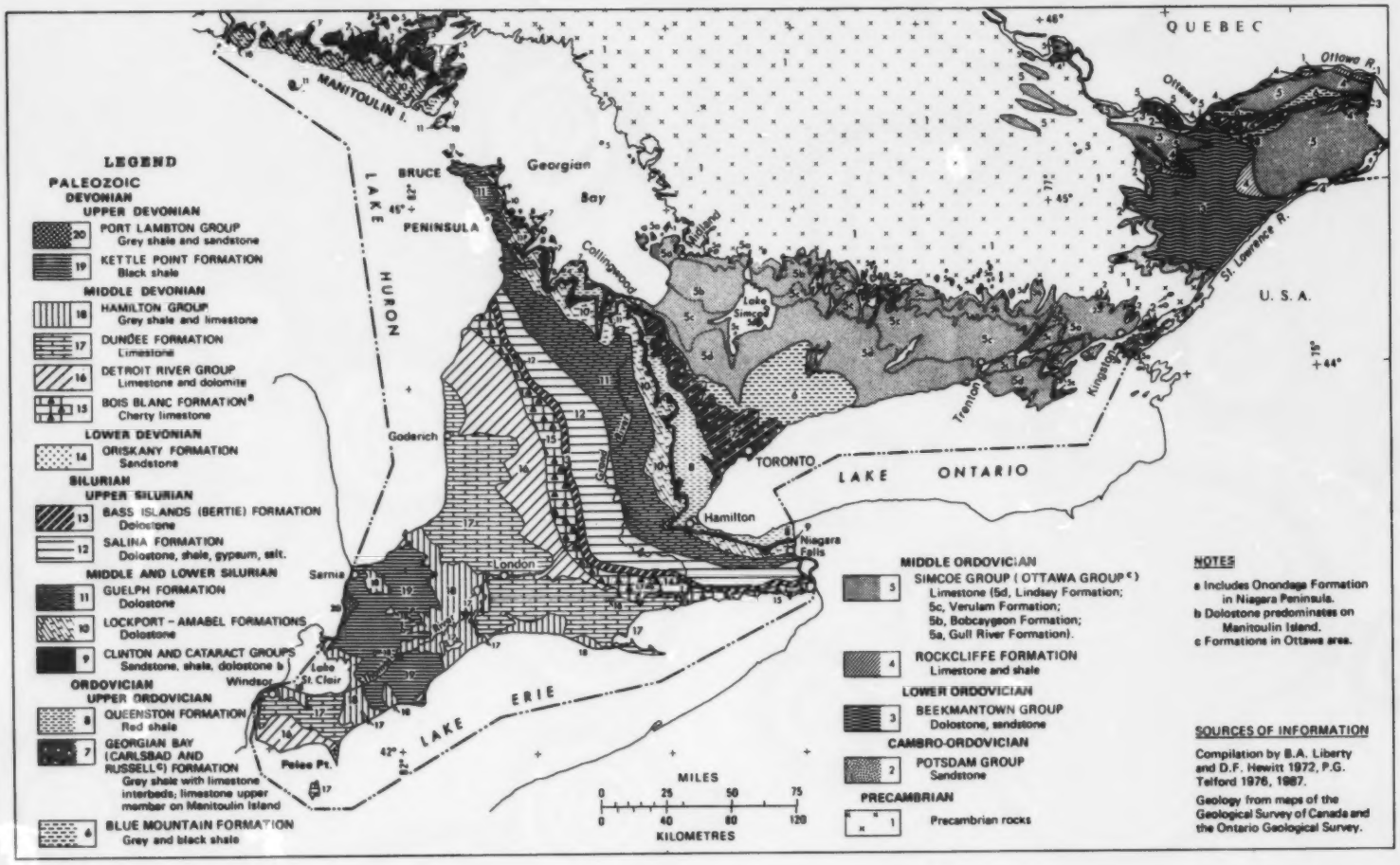

Figure D1. Bedrock Geology of Southern Ontario.

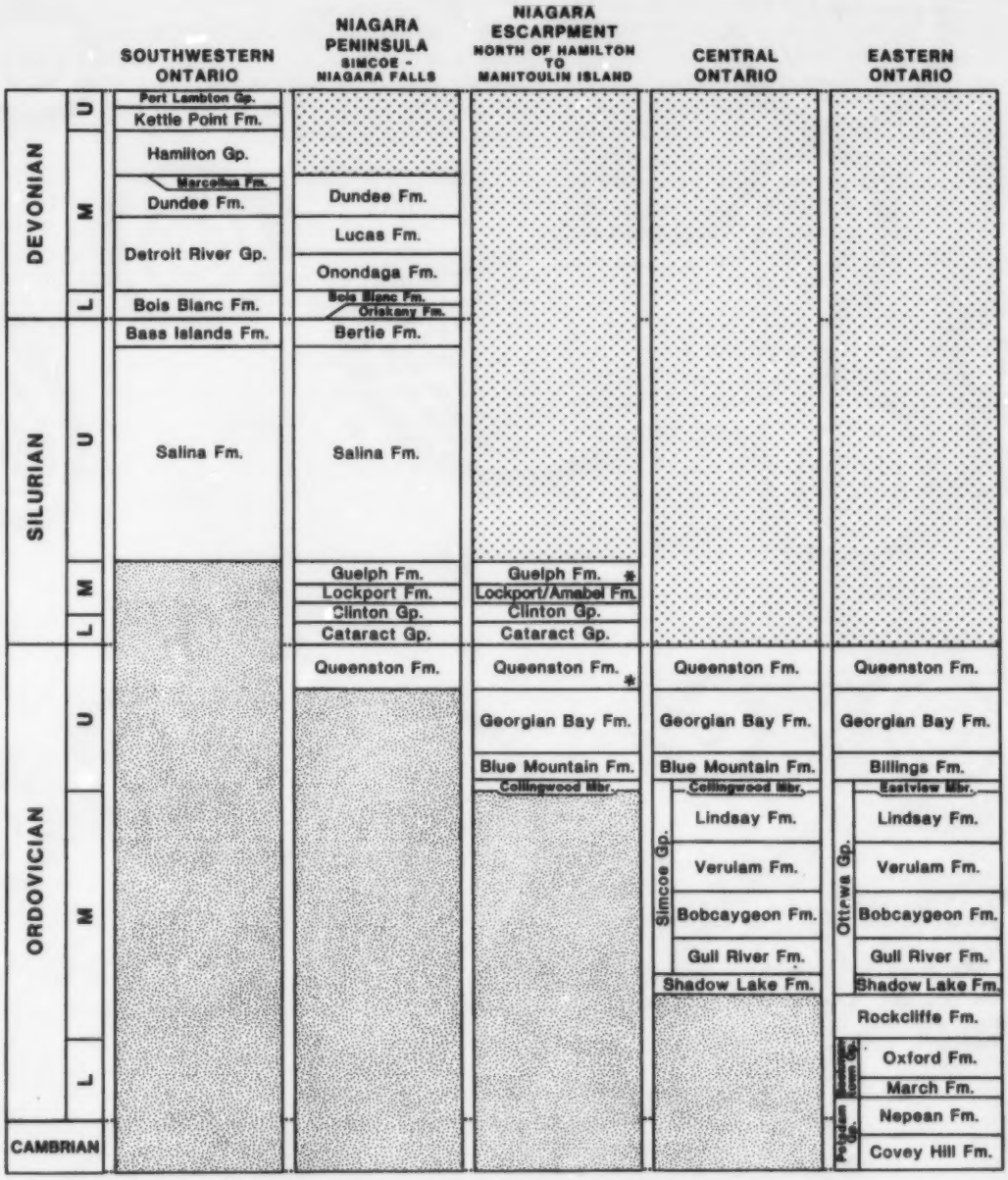

Figure D2. Exposed Paleozoic Stratigraphic Sequences in Southern Ontario
(adapted from: Bezys, R. K., and Johnson, M.D. 1988. The geology of the Paleozoic formations utilized by the limestone industry of Ontario; The Canadian Mining and Metallurgical Bulletin v.81, no.912, p.49–58).

Appendix E — Aggregate Quality Test Specifications

Four types of aggregate quality tests are often performed by the Ontario Ministry of Transportation on sampled material. A description of Table E1 and the specification limits for each test are given in this appendix. Although a specific sample meets or does not meet the specification limits for a certain product, it may or may not be acceptable for that use based on field performance. Additional quality tests other than the four major tests listed in this appendix can be used to determine the suitability of an aggregate. The tests are performed by the Soils and Aggregates Section, Engineering Materials Office, Ontario Ministry of Transportation.

Absorption capacity: Related to the porosity of the rock types of which an aggregate is composed. Porous rocks are subject to disintegration when absorbed liquids freeze and thaw, thus decreasing the strength of the aggregate.

Los Angeles abrasion and impact test: This test measures the resistance to abrasion and the impact strength of aggregate. This gives an idea of the breakdown that can be expected to occur when an aggregate is stockpiled, transported, and placed. Values less than about 35% indicate potentially satisfactory performance for most concrete and asphalt uses. Values of more than 45% indicate that the aggregate may be susceptible to excessive breakdown during handling and placing.

Magnesium sulphate soundness test: This test is designed to simulate the action of freezing and thawing on aggregates. Those aggregates which are susceptible to freezing and thawing will usually break down and give high losses in this test. Values greater than about 12 to 15% indicate potential problems for concrete and asphalt coarse aggregate.

Petrographic examination: Individual aggregate particles in a sample are divided into categories good, fair, poor, and deleterious, based on their rock type (petrography) and knowledge of past field performance. A petrographic number (PN) is calculated. The higher the PN, the lower the quality of the aggregate.

TABLE E1. SELECTED QUALITY REQUIREMENTS FOR MAJOR AGGREGATE PRODUCTS.

	TYPE OF TEST				
	COARSE AGGREGATE				FINE AGGREGATE
TYPE OF MATERIAL	Petrographic Number Maximum	Magnesium Sulphate Soundness – Max. % Loss	Absorption Maximum %	Los Angeles Abrasion Maximum % Loss	Magnesium Sulphate Soundness Maximum % Loss
Granular Base A	200	–	–	60	–
16 mm Crushed Type 'A'	160	–	–	35	–
16 mm Crushed Type 'B'	200	–	–	60	–
Granular Subbase B	250	–	–	–	–
Granular Subbase C	250	–	–	–	–
Granular Subbase D	–	–	–	–	–
Hot Mix – HL 1	100	5	1.0	15	16
Hot Mix – HL 2	–	–	–	–	20
Hot Mix – HL 3	135	12	1.75	35	16
Hot Mix – HL 4	160	12	2.0	35	20
Hot Mix – HL 8	160	15	2.0	35	20
Structural Concrete and Concrete Base	140	12	2.0	35	16
Pavement Concrete and Exposed Structure Deck	125	12	2.0	35	16

(Ministry of Transportation Forms 1002, 1003 and 1010)

CONVERSION FACTORS FOR MEASUREMENTS IN ONTARIO GEOLOGICAL SURVEY PUBLICATIONS

Conversion from SI to Imperial			Conversion from Imperial to SI		
SI Unit	*Multiplied by*	*Gives*	*Imperial Unit*	*Multiplied by*	*Gives*
		LENGTH			
1 mm	0.039 37	inches	1 inch	**25.4**	mm
1 cm	0.393 70	inches	1 inch	**2.54**	cm
1 m	3.280 84	feet	1 foot	**0.304 8**	m
1 m	0.049 709 7	chains	1 chain	20.116 8	m
1 km	0.621 371	miles (statute)	1 mile (statute)	**1.609 344**	km
		AREA			
1 cm^2	0.155 0	square inches	1 square inch	**6.451 6**	cm^2
1 m^2	10.763 9	square feet	1 square foot	**0.092 903 04**	m^2
1 km^2	0.386 10	square miles	1 square mile	2.589 988	km^2
1 ha	2.471 054	acres	1 acre	0.404 685 6	ha
		VOLUME			
1 cm^3	0.061 02	cubic inches	1 cubic inch	**16.387 064**	cm^3
1 m^3	35.314 7	cubic feet	1 cubic foot	0.028 316 85	m^3
1 m^3	1.308 0	cubic yards	1 cubic yard	0.764 555	m^3
		CAPACITY			
1 L	1.759 755	pints	1 pint	0.568 261	L
1 L	0.879 877	quarts	1 quart	1.136 522	L
1 L	0.219 969	gallons	1 gallon	**4.546 090**	L
		MASS			
1 g	0.035 273 96	ounces (avdp)	1 ounce (avdp)	28.349 523	g
1 g	0.032 150 75	ounces (troy)	1 ounce (troy)	**31.103 476 8**	g
1 kg	2.204 62	pounds (avdp)	1 pound (avdp)	**0.453 592 37**	kg
1 kg	0.001 102 3	tons (short)	1 ton (short)	**907.184 74**	kg
1 t	1.102 311	tons (short)	1 ton (short)	**0.907 184 74**	t
1 kg	0.000 984 21	tons (long)	1 ton (long)	**1016.046 908 8**	kg
1 t	0.984 206 5	tons (long)	1 ton (long)	**1.016 046 908 8**	t
		CONCENTRATION			
1 g/t	0.029 166 6	ounce (troy)/ ton (short)	1 ounce (troy)/ ton (short)	34.285 714 2	g/t
1 g/t	0.583 333 33	pennyweights/ ton (short)	1 pennyweight/ ton (short)	1.714 285 7	g/t

OTHER USEFUL CONVERSION FACTORS

	Multiplied by	
1 ounce (troy) per ton (short)	20.0	pennyweights per ton (short)
1 pennyweight per ton (short)	0.05	ounces (troy) per ton (short)

Note: Conversion factors which are in bold type are exact. The conversion factors have been taken from or have been derived from factors given in the Metric Practice Guide for the Canadian Mining and Metallurgical Industries, published by the Mining Association of Canada in co-operation with the Coal Association of Canada.

MAPS
NOT
FILMED

CARTES
OMISES